ARMY RESEARCH LABORATORY

Examination of Human Factors in Networked Sensors in Live and Virtual Environments

by Bruce S. Sterling and Catherine N. Jacobson

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14. ABSTRACT

A demonstration was held with Soldiers operating robotic networked sensors in an actual mock-up of a reconnaissance and surveillance vehicle (HMMWV [high mobility, multipurpose wheeled vehicle]) in the field and in virtual reality simulators. The crew in the live re-supply vehicle (RSV) and the two crews in the virtual simulators consisted of three Soldiers each. The allocation of personnel in both environments was the same: (a) one Soldier served as the vehicle commander and operated the unmanned ground sensors (UGS); (b) one Soldier operated unmanned aerial vehicles (UAVs), and (c) one Soldier operated an unmanned ground vehicle (UGV). Data from surveys and interviews revealed insights into the interface design, sensor and software capabilities, workload, and skills and abilities required of robotic operators. The interface (maneuver command and control [MC2]) was judged as very good for mission planning, but re-tasking sensors to different routes was difficult and time consuming, which resulted in the inability to identify previously detected targets. The imagery on the infrared (IR) UAV sensor, unlike the daylight camera, was not good enough for target identification. The imagery and interface in the virtual simulators was not as good as those on the live vehicle, resulting in higher workload and stress in the virtual simulators. Situational awareness was equal but low in both the live and virtual environments, probably because of technical difficulties, especially in the live RSV. Skills needed in both environments tended to be those necessary to receive information from and send information to higher (*communication*), identify and solve problems concerning sensor coverage (*conceptual*), and recognize targets quickly (*speed loaded*). Visual skills were also needed to interpret sensor feeds and track the sensor on the MC2, especially on the virtual simulators. In terms of important features of the interface and software, the ability to control multiple sensors was deemed vital. Also important were features that enabled operators to provide target identification, location, and spot reports to higher authority. Soldiers stressed the need for high fidelity and "hands-on" training to gain the expertise and confidence needed to operate unmanned sensors. This deficiency in hands-on training could have accounted for some shortcomings of the Soldier-sensor system, which were discovered in the demonstration. Also, technical problems with the live RSV need to be resolved in order to demonstrate the true value of networked sensors in terms of increased area covered, speed, and survivability.

15. SUBJECT TERMS

future combat system; networked sensors; robotic sensors; unmanned aerial vehicle; unmanned ground sensor; unmanned ground vehicle

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1. Introduction

The addition of networked sensors such as unmanned aerial vehicles (UAVs), unmanned ground vehicles (UGVs), and unmanned ground sensors (UGS) to the current and future forces is intended to expand the area that reconnaissance assets can currently cover, the tempo at which reconnaissance assets can operate, and the survivability of reconnaissance assets (particularly manned). Thus, an important question to address is how the addition of these assets affects Soldier workload, stress, situational awareness (SA), skills needed, and ability of Soldiers to perform their reconnaissance mission. It is also important to know if changes could be made in the operator control units (OCUs), which would facilitate efficient and effective Soldier-machine interactions.

Schipani (2003) found that the workload of personnel controlling robotic sensors is affected by several factors. First, the degree of operator intervention necessary affects workload; the more an operator must intervene to direct the path of the sensor, the higher the workload. This parallels findings by Allander and Luck (in preparation), which indicate that the higher the level of automation possessed by robotic sensors (which requires lower levels of operator intervention), the higher the levels of SA (in terms of knowing the current location of the sensor) exhibited by operators. Second, terrain features, specifically difficult terrain, affects workload (Schipani, 2003). Terrain that is difficult to navigate as well as changes in terrain resulting from inclement weather affect robotic operator workload so that the more difficult the terrain and the more changes because of weather, the higher the operator workload. Generally, missions requiring the sensor to travel longer distances also result in higher operator workload. Additionally, more deliberate missions (requiring cautious approaches) result in higher operator workload. These findings suggest that many factors can affect operator workload and that an increase in workload reduces an operator's spare capacity to perform other tasks, such as maintaining SA.

Also, previous research about the control of robotic sensors in a virtual environment shows that control of multiple robotic sensors results in higher workload levels than control of single robotic sensors (Chen, Durlach, Sloan, & Bowens, 2005). The same research also indicates that operators detect no more targets with three robotic sensors than with one. Furthermore, in the study, fewer participants completed the mission within the time limit using three sensors versus using only one, possibly because of the increased workload associated with controlling three robotic sensors simultaneously. These findings parallel those of Dixon, Wickens, and Chang (2003) who found that pilots controlling two UAVs detected fewer targets than pilots controlling one UAV. Similarly, Rehfeld, Jentsch, Curtis, and Fincannon (2005) found that in a virtual urban environment and in difficult scenarios, operators detected fewer targets when they operated two robotic sensors than when they operated only one. The findings outlined suggest that overall, operating sensors incurs a cost in terms of workload and reduced spare capacity to perform other tasks such as target detection.

Conducting evaluations of Soldier control of unmanned platforms for the future force in a live environment is very resource intensive. Live evaluations involve the use of ranges, vehicle platforms for mounting the user interface, numerous test personnel, the use of petroleum, oils, and lubricants (POL), safety and weather considerations. Operations involving flight can be hindered by air space conflicts and restrictions. Evaluation of the control of unmanned platforms in virtual simulation is less resource intensive. It can be performed in an existing battle laboratory setting with a re-configurable vehicle and changes in software, and it can involve fewer test personnel and no POL, weather, or safety considerations. If the virtual evaluation yields similar results to the live one, considerable cost savings could be achieved in the determination of manpower and personnel integration requirements. If the difference is substantial, these data could be used in the development of algorithms for use in battle lab simulations and other models to emulate live versus virtual performance degradation of control of robotic vehicles.

This research has four objectives. The first is to determine the extent to which the use of unmanned reconnaissance platforms affects the performance of Soldiers (workload, stress, SA, the range, and operational tempo), survivability of reconnaissance assets, and the skills needed by Soldiers to effectively perform reconnaissance tasks using these unmanned assets. Although this experiment did not employ a control group using current scout materiel and techniques, we examined the previously mentioned performance variables of Soldiers using the new, unmanned reconnaissance platforms in a tactical but not force-on-force environment, thus potentially reducing operator stress. To mitigate the limitations for comparisons attributable to the absence of currently fielded technologies and techniques, we used subjective ratings of participants who are familiar with current and future materiel and techniques to determine differences in performance between current reconnaissance capabilities and future capabilities, as they are instantiated in this experiment.

The second objective is to assess the Soldier-machine interface through questionnaires and daily after-action reviews (AARs) with all test participants. We queried Soldiers about the system interfaces of the future robotic systems and their OCUs in an effort to examine Soldier-machine interface issues and to reveal needed improvements.

The third objective is to examine human factors differences between live and virtual performance of the sensor systems. We compared the workload, stress, skills needed, and SA of personnel conducting reconnaissance using unmanned sensors in live and virtual simulation.

The fourth objective is to assess the training and to determine how it could be improved to enable Soldiers to better do their jobs as scouts operating networked sensors.

2. Method

2.1 Participants

Participants consisted of nine scouts (military occupational specialty [MOS] 19D). The scouts were divided into three teams consisting of three Soldiers each.

2.2 Test Equipment

The test was executed in two locations, one for the live environment and one for the virtual environment. The virtual environment was represented by three separate Advance Concept Research Tool (ACRT) vehicle simulators, one for each operator. Each operator occupied a stand-alone unit spaced approximately 6+ feet from each other. The three stations were set up in a building on the main post at Fort Knox, Kentucky. The live environment took place in a mock-up of the Future Combat System's reconnaissance surveillance vehicle (RSV) via a modified high mobility multipurpose wheeled vehicle (HMMWV) ambulance. Each test participant occupied one position in the vehicle with one seat reserved for a computer software technician and one jump seat reserved for observers and analysts. The three scout positions and their respective locations within the RSV were (a) vehicle commander (VC) and UGS operator who sat in the right front seat, (b) UAV operator who sat in the left front, and (c) UGV operator who sat in the right rear. The left rear seat was reserved for a computer software technician. The jump seat (for observers and analysts) was a bench that ran across the isle of the HMMWV between the front and rear seats. Figures 1 and 2 illustrate the exterior and interior of the RSV used in the live environment.

For each position (in both the live and virtual environments), there were two screens. The screen to one side (right or left) of the scout displayed the mobile command and control (MC2) screen. This interface allowed the operators to use the MC2 software capabilities via the software menus. For the operation of unmanned assets, the MC2 is used primarily for route planning and adjustments. In addition, the screen contained a map display that also served the MC2 software for UAV and UGV route planning and provided SA for the operators. Routes for the UAV and UGV sensors were planned by assigned way points. We assigned way points by pointing and clicking with the mouse on the MC2 map. The software automatically drew lines connecting the way points. When the way points were saved, this designated the path for the robotic sensor to follow. Re-tasking the sensor before the current path was completed required the elimination of all current way points and the creation of a new set of way points. When MC2 was configured in *networked* mode, positions of all friendly vehicles, including unmanned vehicles, were displayed on the map. Also, any targets posted to the MC2 from sensor feeds (to be explained later) were displayed on the map.

Figure 1. Exterior of RSV (modified HMMWV ambulance).

Figure 2. Interior of RSV shows UAV and VC-UGS operators.

The second screen for each station (located to the right or left of the MC2 screen) contained the unmanned systems (UMS) controller software and allowed operators to manage their unmanned assets and to manage the sensor feeds produced by their assets. Each screen contained slightly different features associated with management of the UAV, UGV, or UGS. For the UAV, the top of the screen had streaming video (30 Hz) of the current view by the one or two UAVs that were flying. When the operator saw something he wanted to post to the map, he clicked on a section of the streaming video to select and produce a picture. These pictures could be kept on the UMS screen display until the operators configured them to be sent to other crew members (e.g., VC) and produced icons on the map display. If the vehicle commander desired, he could send the icon with an appropriate label (e.g., armored personnel carrier) to the network, to be posted on the map displays of all current members of the network (e.g., entire platoon). The bottom of the UAV operator's screen contained information about the UAV such as air speed, altitude, and flight time.

For the UGV operator, the top part of the UMS screen contained pictures taken by the UGV (the UGV did not have streaming video). Again, these pictures could be posted to the operator's map or sent to the VC, who could post them to the network. The bottom part of the UGV operator's screen contained information concerning operation of the UGV, such as speed and fuel levels.

For the UGS operator, the top part of the screen contained pictures taken by the UGS (the UGS did not have streaming video). Again, these pictures could be posted to the VC's map, or the VC could post them to the network. The bottom part of the UGV operator's screen had spot reports from the UGS on location of possible targets. This information consisted of grid location and type of sensor detection (acoustic, seismic). Figures 3 and 4 illustrate the MC2 and UMS displays.

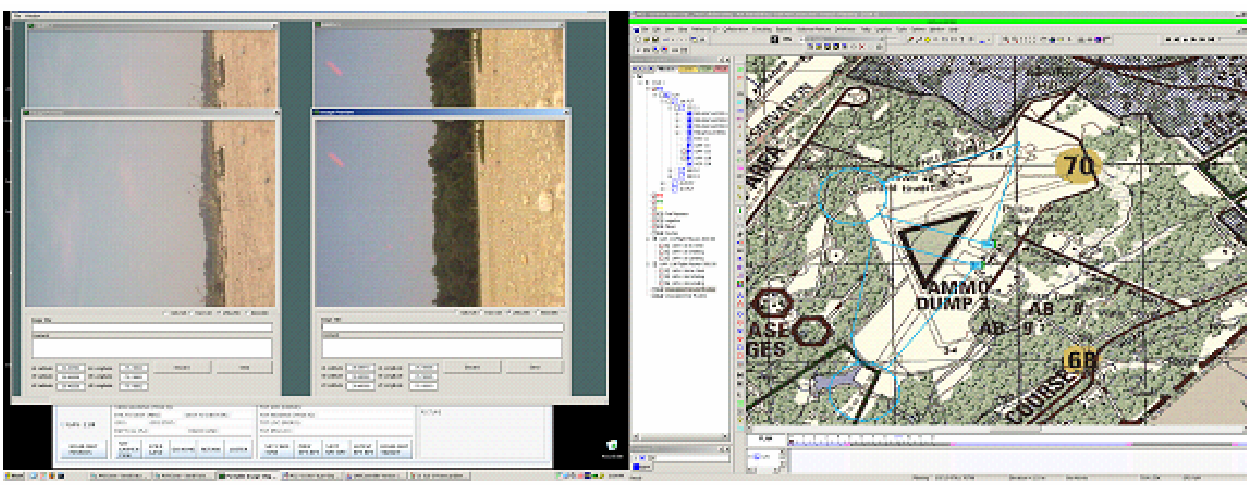

Figure 3. UMS (left) and MC2 (right) with four pictures of UAV (lying on its side).

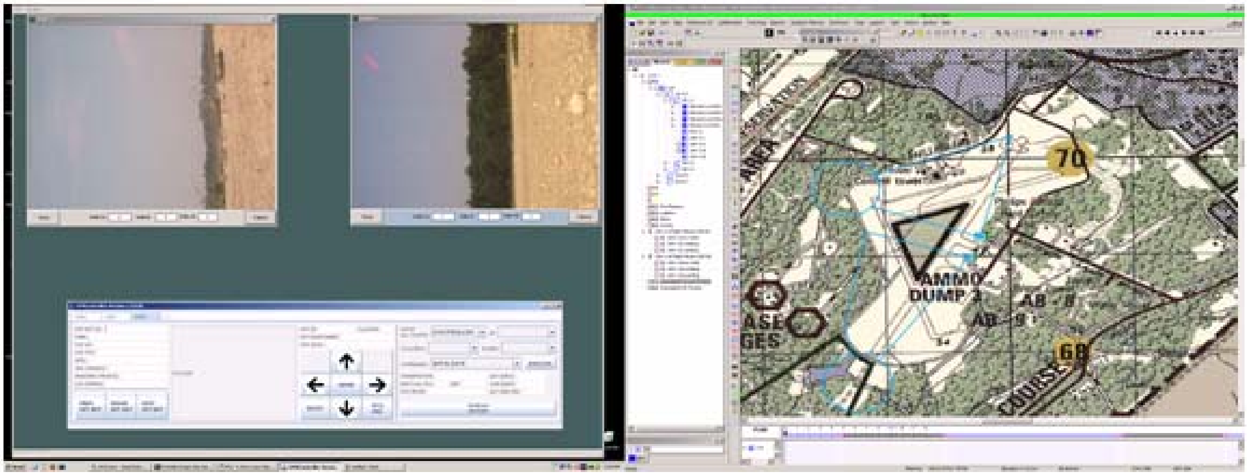

Figure 4. UMS (left) and MC2 (right).

Figures 5 and 6 illustrate the UAVs and the UGV employed in this demonstration. No pictures were taken of the UGS. For a more detailed description of the UMS and MC2 interfaces and operator procedures, see appendix A.

Figure 5. Unmanned aerial vehicles (UAVs).

Figure 6. Unmanned ground vehicle (UGV).

2.3 Instrumentation

2.3.1 Workload

The Bedford Workload Scale (Roscoe, 1984) is a one-item, 10-point assessment of workload. Workload is first assessed on a three-part scale concerning whether it was possible to complete a specified task and whether workload was tolerable or satisfactory. If it was not possible to complete the task, the workload is rated as 10. If the workload is insignificant, a rating of 1 is given. Degrees of tolerability or satisfaction (if applicable) are rated on behaviorally anchored scale points. The instrument is shown in appendix B.

2.3.2 Physiological Measures of Stress

Galvanic skin response (GSR) is a measure of the amount of electrical conductivity on the surface of the skin (usually fingers or palms) that is associated with sweat gland activity. It has long been considered a measure of physiological and mental stress (Fenz & Epstein, 1967). Although there are no absolute levels of GSR indicative of high workload or stress, GSR is a good relative indicator of stress, i.e., higher GSRs for certain tasks or positions suggest higher levels of stress. GSR data were collected with a BodyMedia SenseWear[1] PRO_2 armband. This is a wearable body monitor that enables continuous physiological data collection. It is worn on the back of the upper right arm and collects raw physiological data including movement (used to calculate caloric data), heat flow, skin temperature, ambient temperature, and galvanic skin response. Participants in live and virtual environments had roughly the same ambient temperature in their environment since participants were in air-conditioned areas in both environments (the HMMWV was air conditioned to keep the computers from over-heating). A reading of GSR was taken during training to serve as a baseline reading and to acclimate the participants to wearing the apparatus.

2.3.3 Required Skills

The U.S. Army Research Laboratory (ARL) has developed a computer-based tool called Job Assessment Software System (JASS) (Knapp & Tillman, 1998) to measure skill and ability requirements. JASS was developed from previous work performed by ARL in scaling job demands (Muckler, Seven, & Akman, 1990) and in skill-testing techniques (Rossmeissl, Tillman, Rigg, & Best, 1982). Fleishman and Quaintance (2000) developed the taxonomy of the 50 skills and abilities used in the current version of JASS.

JASS runs on a personal computer in a Windows[2] environment. The program uses a flowchart format and asks a series of questions to which the subject answers “yes” or “no”. “Yes” answers identify the need for a specific skill or ability, and following this, JASS presents a behavioral

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[1]BodyMedia and SenseWear are registered trademarks of BodyMedia, Inc.
[2]Windows is a trademark of Microsoft Corporation.

anchored scale so that the subject can rank the skill demand from 1 to 7. The behavioral descriptions are presented on the scale as "anchor points" to help the subject select a relative score. The behavioral examples that participants use as anchors are written in vernacular language. For example, for the ability "*fluency of idea*," an anchor indicating that a great amount of this ability is needed reads "name all possible problems that might occur with a missile launch," while an anchor indicating that a minimum amount of this ability is needed reads "name four brands of toothpaste." JASS saves the scores in a database for later analysis. A listing of the 50 JASS skills is given in appendix C.

Participants completed the JASS after they completed the exercise. They were asked to assess skills needed to operate networked sensors in the live or virtual environments. It was explained to the Soldier that "operate sensors" involved planning the mission and route or location of the sensors, monitoring the route or position of the sensors, interpreting information provided by sensors, providing information to higher echelon, and providing "target-able" information (i.e., target identification and location), if applicable.

2.3.4 Situation Awareness (SA)

We used a modified version of the Situational Awareness Global Assessment Technique (SAGAT) (Endsley, 2000) to measure SA. Endsley defines SA as "the perception of elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status into near future" (Endsley, 1988).

For this exercise, interruptions were injected at given points. Participants were given a map and then asked to indicate (a) the current position of all target vehicles on the map based, on sensor feeds (perception); (b) the identity of each target vehicle located (e.g., M113A3; target comprehension); and (c) what each target vehicle is doing (e.g., stationary, moving west; orientation comprehension).

Projection (e.g., where the target would be or what it would be doing in the near future) could not be assessed because there was no tactical context or purpose for the targets. That is, the vehicles were not described as an enemy unit or convoy with a presumed mission consisting of "x." Thus, there was no basis for the participants to judge that the vehicle was moving in the direction of an objective and would stop there in a certain time.

The exercise was limited free play, that is, operators of opposing force vehicles were given a route, but one could not predict where they would be at any given time. Thus, the correct responses could not be designated in advance but were scored at exercise pauses by a subject matter expert's (SME's) interpretation of a "ground truth" display. The noncommissioned officer in charge of live operations and the troop commander in charge of virtual operations were designated as the SMEs for this exercise.

Each SME completed the SAGAT, based on "ground truth" from the displays available to the SMEs. In turn, the SAGATs that the SMEs completed served as the basis of "ground truth" for scoring the test participant SAGATs (see figure 7).

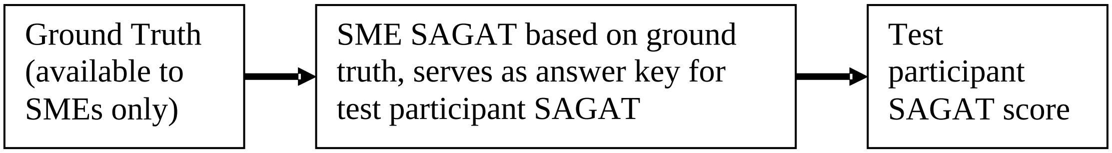

Figure 7. SAGAT scoring.

For scoring test participants' SA on target or enemy location, the SMEs awarded two points if the location indicated by participants was within 100 meters of the actual target (e.g., vehicle) location. If the indicated location was within 200 meters, one point was awarded, and zero points were awarded if the target was more than 200 meters from the indicated position. For scoring test participants' SA on target or enemy description, the SMEs awarded two points if the target was properly identified, (e.g., HMMWV for HMMWV), one point if the target was properly classified (e.g., wheeled vehicle for HMMWV), and zero points if the target was misclassified or not described (e.g., tracked vehicle for HMMWV). For scoring test participants' SA on enemy or target activity in terms of posture (i.e., moving or stationary) and orientation (e.g., east or west), SMEs gave two points if both posture and orientation were properly given (e.g., moving west for moving west), one point if posture was given correctly (e.g., moving east for moving west), and zero points if posture was incorrect or not given (e.g., moving east for a vehicle actually stationary). The scores were computed as a percentage of the total possible score. There were four possible targets for each of the live RSV runs. For the virtual runs, there were five targets for the first run and eight for the second. An example of the SAGAT is presented in appendix D.

It could be argued that all three aspects of SA that we measured constitute a sub-set of what Endsley considers perception (where a target is located, the identity of the target, and the orientation of the target). Comprehension in the usual sense[3] was impossible because, as explained before, no tactical scenario was given to participants, just targets at certain locations.

2.3.5 Networked Sensors Questionnaires

Questionnaires concerning perceived changes in size of area covered, speed of reconnaissance, and survivability of the manned platforms were administered after completion of the integrated sensors exercise. See appendix E for these questionnaires and for the participant comments.

[3]For example, an armored personnel carrier suggests that there are infantry, which means the opposing force could be looking for the arms cache suspected to be in the area.

2.3.6 Importance of Human-Robotic Interface (HRI) Features

A generic questionnaire concerning perceived importance of specific features of the OCU and of tasks associated with controlling and monitoring robotic assets was administered. The questionnaire and participant comments are shown in appendix F.

2.3.7 Interface Questionnaires and AARs

We assessed interface design via two methods: we used questionnaires (see appendix G for questionnaire and participant comments) and we asked questions concerning human factors issues on the interfaces during the AARs held after all relevant sub-tests (e.g., separate sub-tests for UAV, UGV, and UGS). See appendix H for interview protocols and interview comments.

2.3.8 Performance Measures

The test plan called for the testing at Fort Knox to generate test data that would demonstrate the degree to which the sensors met their exit criteria. Measurements of reported locations of acquired targets, range to target, and target locating error would be used to quantify observations of how precisely targets could be located and reported.

Central to this was a system that would allow target locations to be precisely recorded during a trial. The location of targets found by the sensor operators would be recorded by an analyst in the RSV who would record time and grid location and type of target the scout announced. These locations would then be correlated to actual target locations recorded at that same by the target location and recording system used.

During the planned trials at St Vith and Training Area (TA) 6, Fort Knox, a night vision system would have recorded time-tagged global positioning system locations of a limited number of the target sets. This period was originally designated to train operators on the actual equipment and to enable trials to be run that would examine the exit criteria metrics of the sensors. The technical difficulties of having the sensors available for a complete trial during the St Vith work made collection of target data impossible. The systems simply were not operating well enough and reliably enough to complete an actual trial. Thus, no data were available from that phase of the testing.

During the subsequent operations at TAs 8, 9, and 10, also at Fort Knox, three trials were completed in which reported locations of targets acquired by the crew were recorded by data collectors. Target locations during this period were obtained via the Deployable Instrumented Training System (DITS). This system recorded time-tagged grid locations of all equipped targets in the testing area. These data were collected for the three trials conducted during this period.

A post-test analysis of the crew-reported locations of targets compared to actual target locations at the same time showed several anomalies in the data. The “actual” reported locations of the six instrumented targets showed considerable variations in accuracy for some systems. Data were collected approximately every 20 seconds. Six-digit coordinates for the locations were pulled from the database at the times when crews reported acquiring a target. It was noted that that location for a particular target could vary by 100 meters or more from the report given 20 seconds previously. Sometimes the variation was more than 1200 meters. In some cases, it appeared that the location of another target was entered by the system for the location of the target of interest. They seemed to "swap reported locations." These inconsistencies made determination of a true "ground truth" impossible. Since "ground truth" location could not be calculated with any reliability, it was impossible to calculate the error between where the target was located and where the target was reported by the sensor operator. Therefore, this part of the data analysis was reluctantly omitted.

2.3.9 Anthropometric Measures

In order to help interpret some of the responses to interface design, standard anthropometric measures used in platform assessments were taken from all test participants. The instrument is provided in appendix I.

2.3.10 Training Survey

A survey was administered to test participants after they had been trained and received "hands-on" practice using the live interface. The training survey is in appendix J.

2.4 Training

Test participants received 5 days of classroom training and 5 days of field training. Classroom time provided the test participants a chance to become familiar with the features of MC2 and to learn the software menu system to the extent that it related to their imminent roles and operators of unmanned assets. Field training gave participants the opportunity for some hands-on experience using MC2. Classroom training was somewhat structured while field training involved more free play and simply a chance for the test participants to become more familiar with their test duty positions.

2.5 Procedure

Anthropometric and baseline GSR measures were taken during participant classroom training the first week of the exercise. Questionnaires and AARs concerning the sensor interfaces were also administered at the completion of hands-on training the following week.

A live–virtual demonstration at the Unit of Action Maneuver Battle Lab (UAMBL), Fort Knox, in the third week involved crews of two simulated reconnaissance and surveillance vehicles (R&SV) in the mounted warfare simulation center and one crew of a surrogate R&SV (HMMWV with three workstations) on training areas at Fort Knox. Both live and virtual crews controlled as many as three UAVs, one UGV, and 35 UGS. One crew member acted as VC (lead scout) and monitored sensor feeds from the UGS. One crew member designated way points and monitored streaming video from the UAV. One crew member designated way points and monitored snapshots from the UGV.

Armband and SA data were collected in trials where technical difficulties did not interfere severely with participants performing their jobs. The SenseWear PRO_2 armbands were also worn during the third week of the test. Armband data for the live RSV group were collected for two afternoon runs and one morning run. Armband data for the virtual group were collected for two morning runs and one afternoon run. SA measures for the live RSV were collected for three afternoon runs. The SA measures were collected from one virtual crew for an afternoon run and from two virtual crews for a morning run. Data were not collected at other times because technical difficulties precluded meaningful target detection.

Workload measures were collected for the same time periods, except with the addition of one afternoon run for the live crew. It was judged that although technical difficulties prevented assessment of SA, the workload measure was valid.

The networked sensors questionnaire (on the integrated performance of the sensors) and JASS were administered after live and virtual trials were completed. For more details about the experimental scenarios, see appendix L.

3. Results

3.1 Anthropometrics and Demographics

The anthropometric data shown in figure 8 indicate that the sample population was at or above the Army population average on all collected measures; the sample tended to be a group of large Soldiers. As height and weight tended to be above the Army population average, it makes sense that other measures are above average as well. Nine of the ten (the troop commander included) did not need corrective lenses and one test participant wore lenses for myopia. Surprisingly, fully half of the sample was left handed. The rest were right handed (versus ambidextrous).

The sample for this exercise consisted of three captains, one sergeant (E5), and five staff sergeants (E6). The average age was approximately 33, with roughly 12 years in the Army. For the enlisted Soldiers' MOS, four were tank crewmen (19K) and two were scouts (19D). For the officers, one each was from military intelligence, armor and infantry branch. Only two personnel had previously participated in other experiments using computer interfaces. These two personnel averaged five such experiments (three and seven).

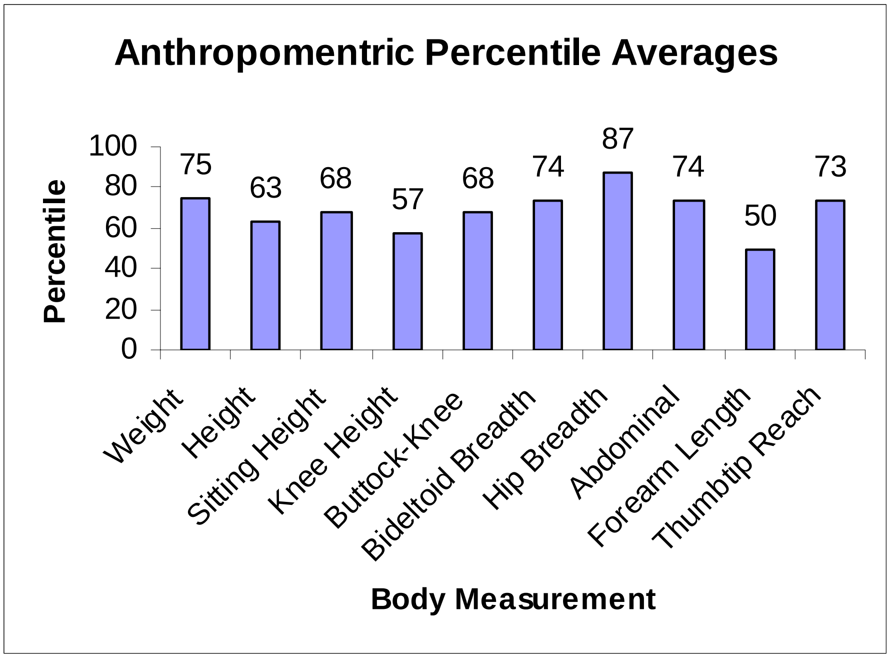

Figure 8. Anthropometric data.

3.2 Objective 1: How Does the Use of Unmanned Reconnaissance Assets Affect Soldier Performance (live crew only)?

3.2.1 Workload

Workload data were collected from the live crew at breaks in the mission when the SAGAT was also administered. The findings are reported in table 1. The workload ratings across all missions and positions indicate very moderate levels of workload based on a 10-point scale. The average of these ratings (2.9) reflects individual responses that are associated with the behavioral anchors of *workload low* and workload allows *enough spare capacity for all desirable additional tasks.* Several factors may have affected the moderate workload levels. First, there was frequently only one (versus two) UAVs flying. Furthermore, operators frequently could only use the infrared camera, which did not provide good imagery, thus making it unlikely that a target would be sighted. Second, the UGV often lost connectivity, leaving the operator with nothing to do since his asset could not be used. Third, the inability of the UGV to take pictures while moving resulted in low workload for the operator while it was running the route specified during planning. Fourth, the UGS camera was not working, thus reducing the VC's role as a UGS operator to monitoring spot reports about the location of detected targets. Without imagery, the UGS auditory and seismic sensors could (at best) only detect a moving vehicle of some sort.

Table 1. Workload for live crew by mission and sensor management.

Task	Avg across missions	Mission 1	Mission 2	Mission 3	Mission 4	Avg across UAVs	Avg across UGVs	Avg across VC and UGSs
Overall workload	2.9	3.3	3	2.5	2.7	3	2.8	3
Plan sensor route location	2.5	2.7	2.7	2.5	2	3	2.5	1.7
Monitor sensor route location	2.6	2.7	2.7	3	2.3	3	2.8	2
Interpret sensor feeds	3	3.3	3.3	2	3	3	2.8	3.3
Provide information to higher echelon	3	3	3.5	2.5	3	3	3	3
Provide target-able information	3	3	3.7	2	3	3	2.8	3.3

Workload levels reported in the networked sensors survey administered at the end of the exercise (see figure 9) were slightly higher than those levels reported during the exercise (see table 1). However, these workload ratings included participants using live and virtual sensors. Figure 9 illustrates that the average workload level ranged from 2.3 (low workload) to 5.1 (workload high enough that additional tasks could not be given the desired amount of attention). The average workload level reported was 4.7, which indicates that workload was high enough that easy attention could not be given to additional tasks. The lowest workload was for planning sensor route, which seems in line with ratings of MC2 planning tools discussed next.

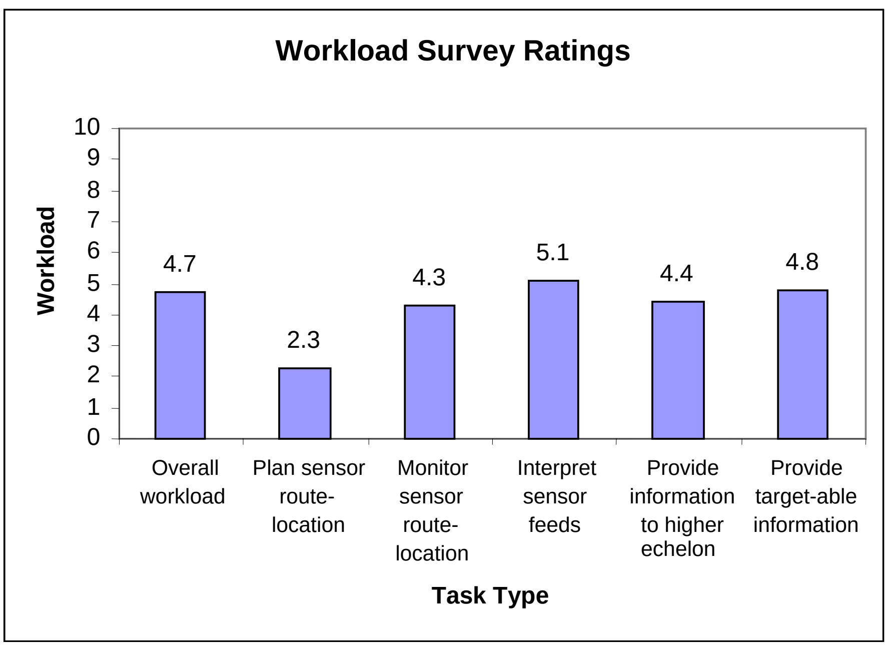

Figure 9. Workload ratings from networked sensors survey.

3.2.2 Stress

The stress levels of all three live RSV positions in figure 10 follow a similar pattern with reported workload levels but were somewhat elevated for the VC (who was absent on Day 1). The GSR increased slightly from baseline to Day 1 post mission, then declined slightly for Day 2 Mission 1. It increased dramatically before and during the second mission of Day 2. The second mission on Day 2 (marked by increased GSR levels) was the first attempt to hold joint live and virtual missions, where the live and virtual crews could share information over the MC2. The technical staff was attempting to establish "connectivity" between live and virtual simulations, and the mission was fraught with technical problems. This may have accounted for the added stress on this mission. It is possible that because of the VC's added responsibilities, he experienced more stress, but as a single data point, extrapolation from these data is difficult.

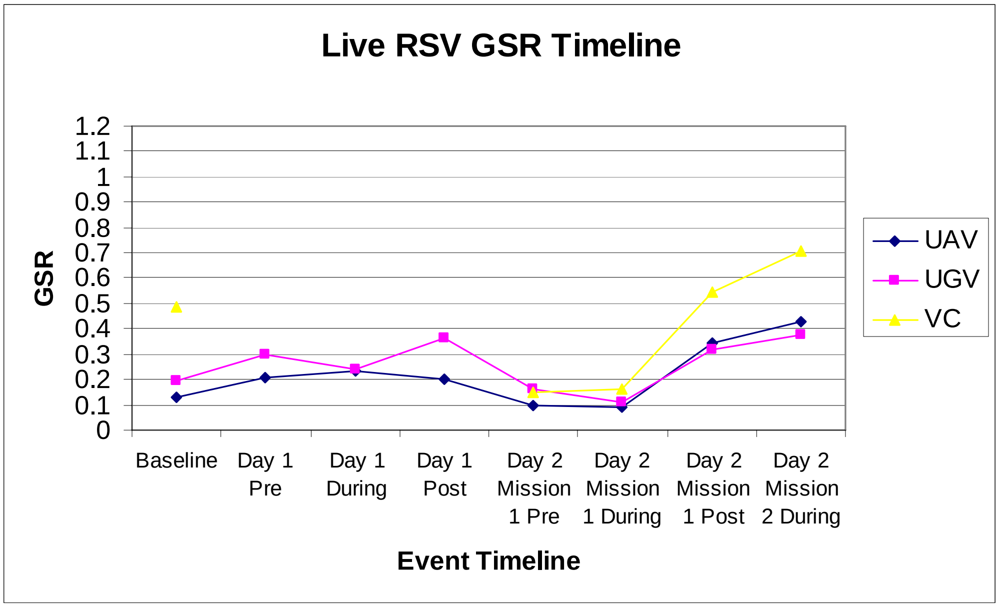

Figure 10. Live RSV GSR timeline.

Skin temperature (see figure 11) somewhat reflects the pattern of rising from baseline to Day 1 post mission, then declining (but more dramatically than GSR) to Day 2 Mission 1 pre-mission. It also continued to rise from Day 2 Mission 1 pre-mission to Day 2 Mission 2 during mission but not as dramatically as the GSR did for the UAV operator and VC, whose GSR levels greatly exceeded Day 2 Mission 1 levels. The pattern of data for GSR and skin temperature is closest for the UGV operator, who experienced the least amount of work within the live crew, because of frequent loss of connectivity to his UGV. Thus it seems as if the fluctuations in heat could only partially account for the fluctuations in GSR.

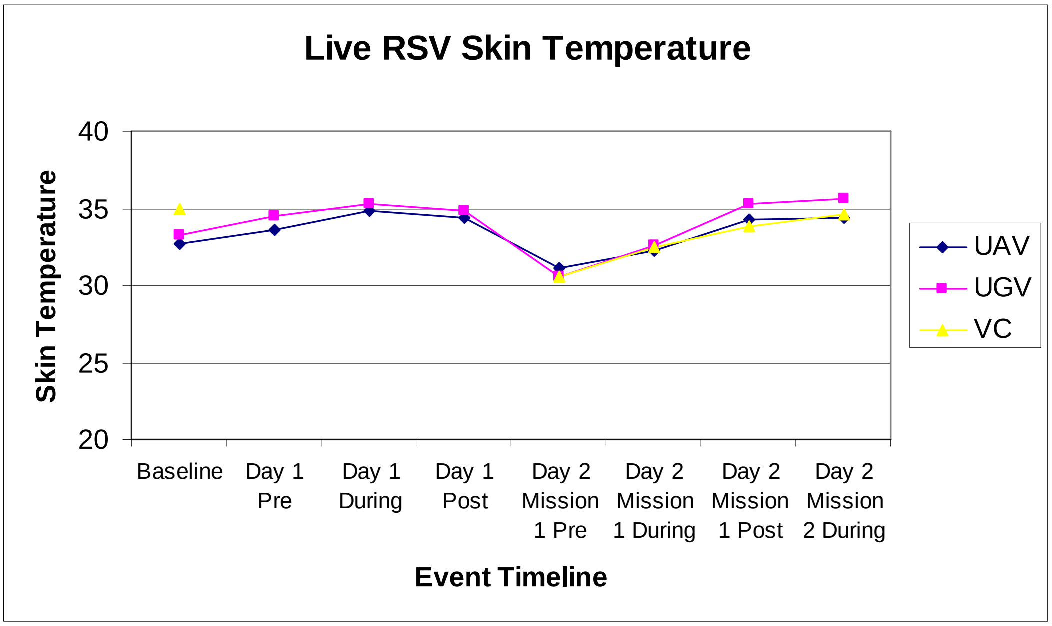

Figure 11. Live RSV skin temperature.

Skin temperature data are presented in order to ensure that environmental stressors did not account for the GSR pattern. Although the RSV was air conditioned, technical personnel constantly entering and leaving the vehicle through plastic curtains in the rear allowed the temperature to perhaps reflect the ambient air temperature to a greater extent than in the virtual realm, which was a rather large air-conditioned building.

3.2.3 Situational Awareness

SA was measured as a percentage of correct answers provided in the SAGAT of a total score of 100%. As shown in figure 12, SA for the live RSV crew was relatively low, with the overall level of around 30% for the VC and UAV operator. The UGV operator's SA was the lowest at approximately 7%. As with the workload data, the low level of SA could be attributable to technical problems, such as only one UAV flying (and mostly with the IR camera and not the daylight camera), the UGV frequently losing connectivity, and the UGS not having a camera.

The SA was higher for the UAV operator and the VC (who operated the UGS), relative to the UGV operator. From observation in the vehicle, the VC detected the most targets, with the UAV operator detecting the next highest amount. Because of technical difficulties, the UGV operator detected relatively few targets. It makes sense that the VC had slightly better SA on location and activity of targets, while the UAV operator had better information about description, since that is the type of information each sensor provided. That is, the UGS provided location and movement of a detection, based on seismic or acoustic information. The UGS, however, could not provide much information about what was detected, other than whether it was a vehicle of some sort. Since the UAV had a camera, it could provide information about what the UGS detection might be.

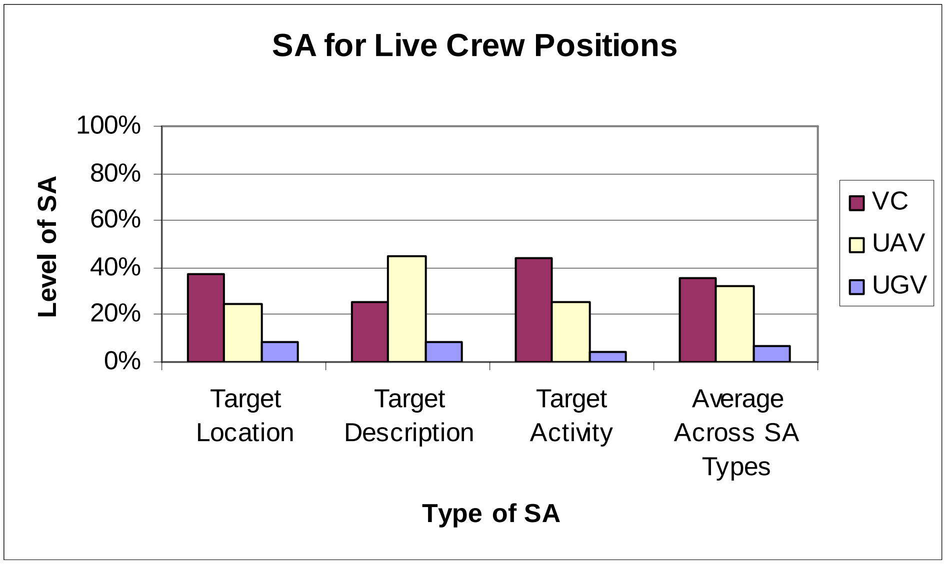

Figure 12. SA for live crew positions.

3.2.4 Networked Sensors Questionnaire

3.2.4.1 Area of Coverage (see appendix M, table M-1)

Most of the respondents rated the area coverage for networked sensors as greater than that covered by current systems for all but one item (overall area covered). Here, the respondents were evenly divided between the same coverage and more coverage. Survey written comments revealed that one respondent was concerned about additional information and resulting workload limiting effective coverage. Two respondents indicated that coverage is highly dependent on terrain (e.g., wooded terrain results in less area covered than desert terrain), and one respondent indicated that a "mix" of sensors is necessary to move from target detection to identification.

3.2.4.2 Speed of Reconnaissance (see appendix M, table M-2)

Most respondents rated networked sensors as faster than current systems in planning and deploying assets but of equivalent speed as current assets in completing route reconnaissance. No majority occurred in any category concerning speed of completing area or zone reconnaissance. Two participants commented that the systems frequently were not working, which affected their assessment of speed of reconnaissance.

3.2.4.3 Survivability (see appendix M, table M-3)

Most respondents rated manned platforms using networked sensors as less survivable than scouts using current systems against threats from armored vehicles, mortars, rocket-propelled grenades, small arms, and improvised exploding devices (IEDs). No consensus occurred concerning threats from artillery or survivability for different reconnaissance tasks, although most ratings indicated that survivability was the same or less for manned platforms using networked sensors compared to current systems. One respondent indicated that his point of comparison was an M1A1 tank. Another indicated that the UGV was more vulnerable since it had to stay on the roads and another Soldier indicated that additional Soldiers on the ground would provide local security.

3.2.4.4 Ability to Detect Targets (see appendix M, table M-4)

Two-thirds of all respondents rated networked sensors positively for detecting wheeled and tracked vehicles and company-sized formations. Respondents were less positive about detecting dismounts, squad- or platoon-sized entities. These results suggest that respondents believe that vehicles are detectable, but infantry (except for company-sized units) are not. Written comments indicated dissatisfaction with the lack of dismounts as targets in the exercise, and some respondents were not certain if they did not detect dismounts or if dismounts were not injected into the exercise (they were not). One respondent indicated that he could not distinguish wheeled from tracked vehicles. Another indicated that the UAV flew too high to detect targets (especially true in virtual simulation). One respondent indicated that while targets could be detected, recognition and identification was another matter.

3.2.4.5 Providing Target-able Data (see appendix M, table M-5)

Overall, ratings were mostly “amber” and “red” concerning target acquisition, suggesting that the information received from sensors may not be good enough to be used beyond simple detection; thus that which is detected cannot rise to the level of becoming reliable targets. While few respondents indicated they could detect, classify, recognize, identify, or provide target location on dismounts, two-thirds indicated they could provide timely information about dismounts. Concerning wheeled vehicles, the only “green” category was the ability to detect a target. For tracked vehicles, the only “green” category was (rather incongruously) ability to provide timely information. No areas were “green” for target acquisition of IEDs. One Soldier commented that only the camera on the UGV could provide target-able data. Another opined that he did not know how the sensors could detect IEDs unless the UGV hit one. Comments during the AAR suggested that the live UGV provided good imagery when it worked properly (the live UGV frequently lost connectivity and could not send pictures while moving). Although the live UAV daylight camera generally provided good imagery, the UAV that was most frequently used was outfitted with an IR camera, which provided lower quality imagery. Also, even though the daylight camera on the live UAV provided good imagery, it frequently had to be re-tasked to identify what it detected before continuing on its route. Re-tasking was very difficult and time consuming. Because of the limitations stated, the promise of these live sensors was generally not realized in this demonstration.

3.2.5 Skills Needed

3.2.5.1 Skills Needed for Live Operation

JASS groups skills into seven clusters: *communication, conceptualization, reasoning, speed loaded, vision, audition, psychomotor*, and *gross motor*. Figure 13 shows that there were three clusters with ratings above the mid-point of the scales (3.5 on a scale of 0 to 7), suggesting a relatively high need for these skills in order for Soldiers to accomplish the tasks involved in operating the unmanned sensors. These skills were *communication, conceptualization*, and *speed loaded*. *Communication* involves the ability to understand and be understood in oral and written communication. The *conceptual* cluster involves skills such as memorization, ability to concentrate on a task and to ignore distracting stimuli (selective attention), ability to think creatively to solve problems (originality, fluency of ideas), and ability to identify potential problems (problem sensitivity). *Speed loaded* involves skills such as the ability to shift between different sources of information (time sharing), quickly recognize patterns (speed of closure), and quickly compare patterns (perceptual speed and accuracy). The reported need for these three skill clusters suggests that personnel are receiving information and providing information to others (vehicle command, platoon leader, troop commander), attempting to adjust plans based on new information or problems with sensors, while working with the interface, and interpreting sensor input in a time-sensitive environment.

One skill cluster (*vision*) had a mean of ~3.0. *Vision* refers to visual acuity (near vision, far vision, night vision, day vision). This ability is needed to track the position of the sensor on the MC2, while one is interpreting sensor data on the UCMS.

The remaining skill clusters, in descending order of importance, were *reasoning, psychomotor, audition*, and *gross motor*. *Reasoning* involves mainly mathematical ability. *Psychomotor* skills involve coordination or fine muscle movements. *Audition* involves skills such as general hearing and the ability to focus on a single source of auditory information (auditory attention). *Gross motor* involves skills such as multi-limb coordination, strength, stamina, and speed. These skills were not judged to be very necessary to operate sensors in the RSV since they received scores of less than 2.5 on a 7-point scale.

Figure 14 contains skill data for live operators by position. Although the following conclusions are based on only one person per position, the VC and UAV operator indicated the highest need for skills, with the VC as the higher of the two. In fact, the VC expressed a reasonably high need (4.0 or more on a 7-point scale) for all skill clusters except *gross motor*. The low requirements of the UGV operator seem to track with observations in the vehicle, with the UGV operator having relatively little to do because of frequent loss of connectivity to the UGV, plus the UGV camera not being able to work while moving.

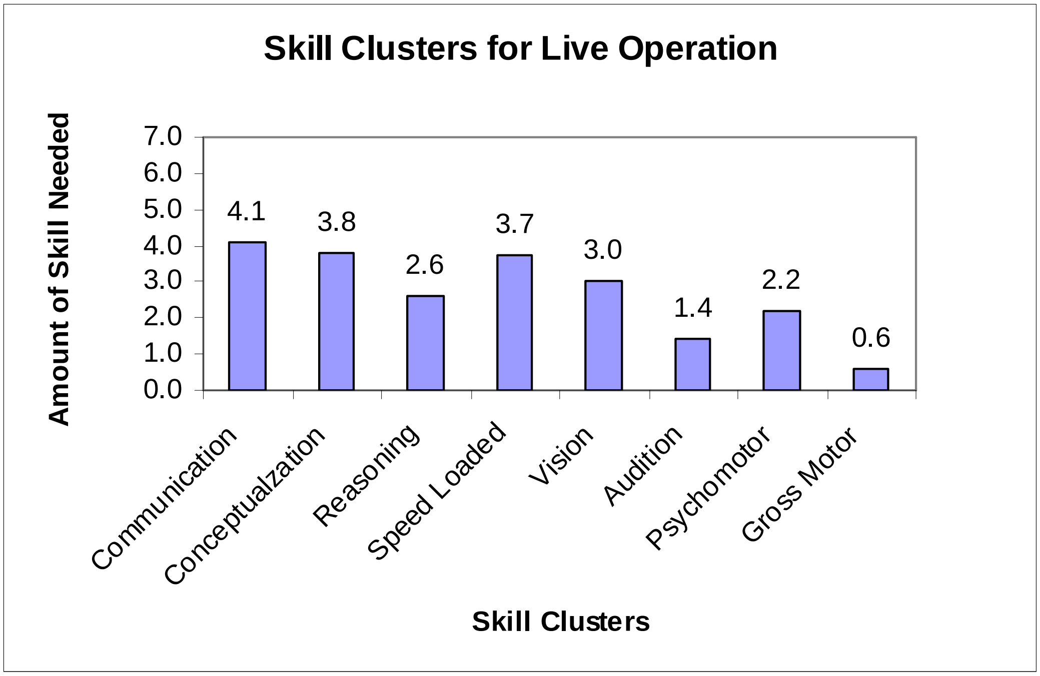

Figure 13. Skill clusters for live operations.

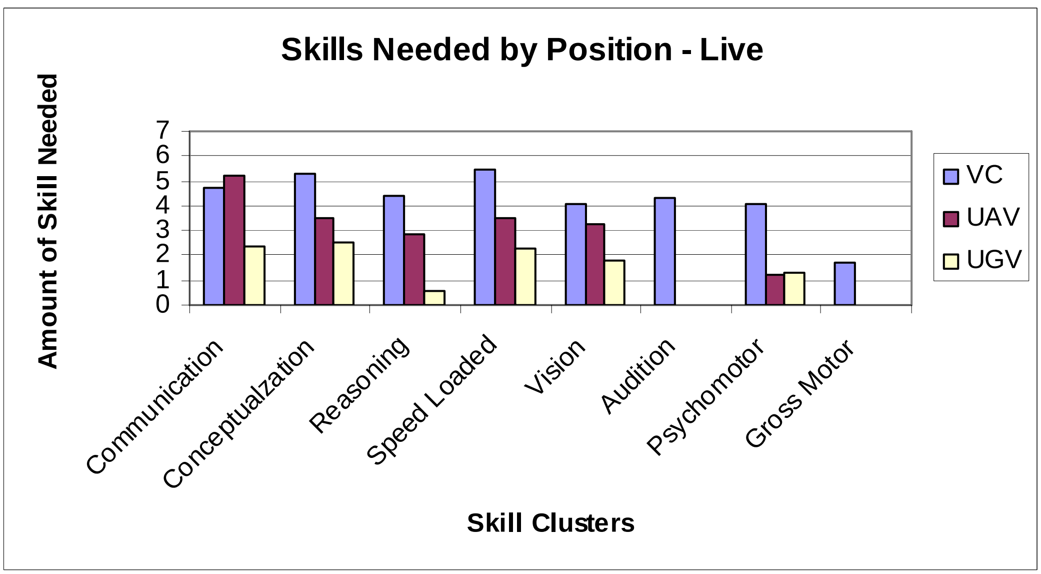

Figure 14. Skills needed by position – live.

3.3 Objective 2: Assessment of Soldier-Machine Interface

3.3.1 MC2

Survey results in appendix M, table M-6, and AAR comments showed that MC2 sensor planning tools were viewed positively for all three sensors. Also, monitoring the current location of the sensor and sending spot reports were viewed positively. Altering the routes of sensors (UAV and UGV) was a major problem highlighted in the survey results and AAR comments. Re-tasking the sensors was difficult, time consuming, and often did not work. For the UAV, operators often had to delete the current route and begin again. One UAV operator suggested a joy-stick to tele-operate the UAV during re-tasking. Another problem that was observed related to MC2 concerned going into the collaboration mode where individual plans for sensor routes were shared among the crew members during execution. Frequently, plans were lost because the developer was in collaboration mode while making the plans rather than making them apart from collaboration and then joining a collaborative session. The procedures for who joined collaboration and when, were complex and not infrequently caused plans to be lost.

Mission planning tools in MC2 (see appendix M, table M-7) were also uniformly positively evaluated by respondents. One respondent commented that MC2 is a very good mission planning tool. Another respondent commented that editing a route must be made easier, thus corroborating observations made in the “live” RSV. Two respondents commented that they did not use several of the tools listed. Another respondent commented that when MC2 does not crash, it works well.

3.3.2 UMCS

Appendix M, table M-8, reflects the problems that were reported in launching the UAV. One respondent indicated that he was too small to launch the UAV and suggested some sort of launching mechanism such as a catapult. Another respondent indicated that there should be a pre-flight checklist and a UAV self-test so that two people were not required to test the UAV before flight.

In table M-9, the major problem on the UMCS was sensor imagery. Although it was easy enough to get a bird’s eye view of what the UAV was seeing, getting good quality imagery sufficient to get target-able information was difficult. Difficulty in getting target-able information was reported for all three sensors. On the UAV, one operator noted that there is no arrow to indicate cardinal direction on the pictures captured by the operator, so it is difficult to determine the direction of the target. On the UGS, the camera was not designed to work while moving so the operator had to complete the route before being able to see targets. Comments on the survey indicated a need to better direct the cameras on the UAV and UGV (the sensor view could only be changed by changing the position of the UAV or UGV itself). The inability to easily re-task prevented the operator from altering a route to pursue a UGS or UAV detection. The camera was not working on the UGS, so only acoustic and seismic data were available for that sensor during the test. A related difficulty for the UGS was that it was difficult to tell if multiple detections indicated one target detected many times or multiple targets. Some degree of sensor fusion is needed, rather than the operator having to interpret the data. In the final AAR, the troop commander suggested that spot reports be fused and represented as an icon on the map.

This level of sensor fusion was an available feature of the sensor software, so this comment may be a reflection of a training issue.

3.3.3 Importance of Interface Capabilities

Appendix M, table M-9, indicates that Soldiers felt that all of the control unit capabilities are important at the very least since all items were rated as 5 or more on a 7-point scale. Especially important is the ability to control one small UAV and to be able to monitor multiple sensors.

3.3.4 Importance of Interface Characteristics

The data shown in appendix M, table M-10, indicate that, with the exception of voice recognition, all interface characteristics presented to Soldiers in the survey were considered important at the least, since Soldiers provided ratings of 5 on a 7-point scale. Especially important are digital maps, the ability to capture and transmit digital images, quality of video images, and detection range of the interface. These features seem to relate to Soldiers being able to identify entities and their location and send spot reports with images of the entities.

3.4 Objective 3: Live Versus Virtual Networked Sensors

3.4.1 Workload

Figure 15 shows that except for planning sensor routes, the workload for Soldiers operating in the virtual environment was considerably higher than for live. In live mode, the workload was generally rated with scores relating from workload low to *enough spare capacity* to perform additional tasks, while in virtual workload, ratings indicated that the Soldiers had *insufficient spare capacity* or *reduced spare capacity to perform additional tasks*. The higher workload levels reported in the virtual mode are likely because operators had to place icons on the maps themselves versus live mode when icons were plotted automatically. Also, the imagery detected by the sensors and presented on the unmanned systems controller (UMSC) was more difficult to see in the virtual world. Finally, these two difficulties often resulted in multiple spot reports being sent to the VC, all of which could have resulted in the increased workload reported in the virtual mode.

Figure 16 indicates that workload in the virtual environment was much higher for the UAV operator and VC than for the UGV operator. Except for the task of planning the sensor route, workload ratings of the UAV operator indicate that, at most, he had *little spare capacity* to perform additional tasks since the workload ratings were at least 6 or greater on a 10-point scale. In the final AAR, it was the UAV operators who mentioned difficulties with the interface in detecting and identifying targets, plotting them on the MC2, and sending reports to higher echelon. Difficulties with the interface could have likely resulted in increased workload reported by the UAV operators in virtual mode.

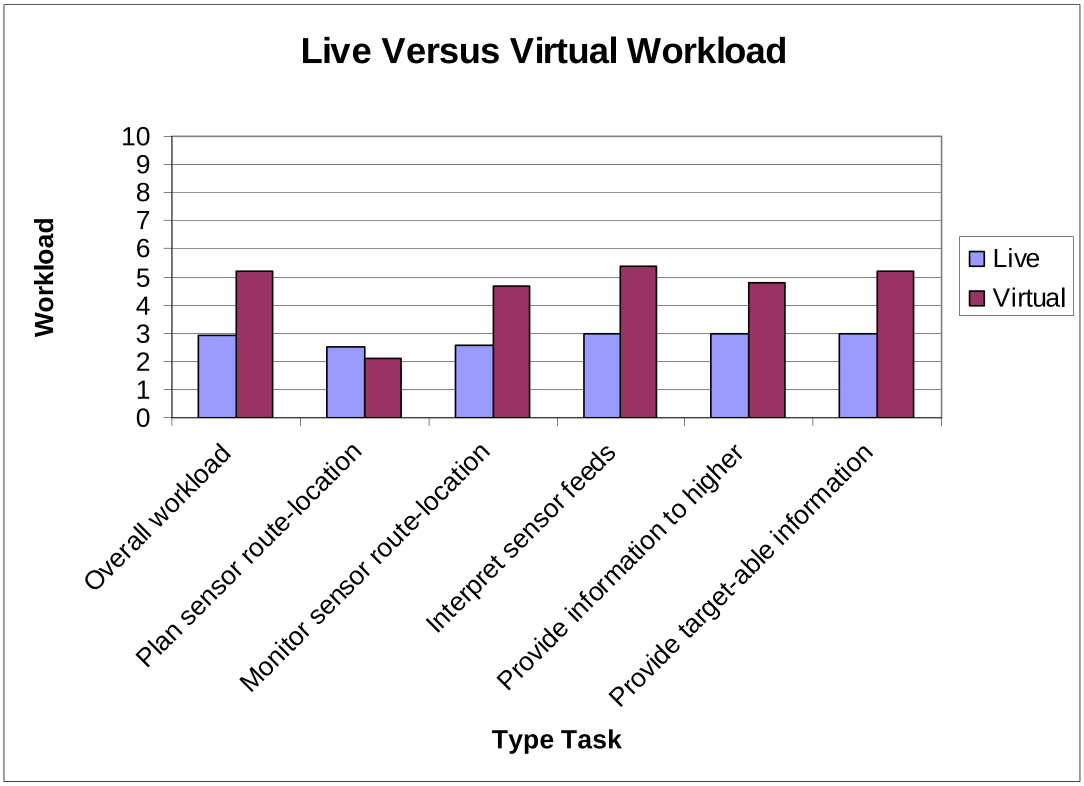

Figure 15. Live versus virtual workload.

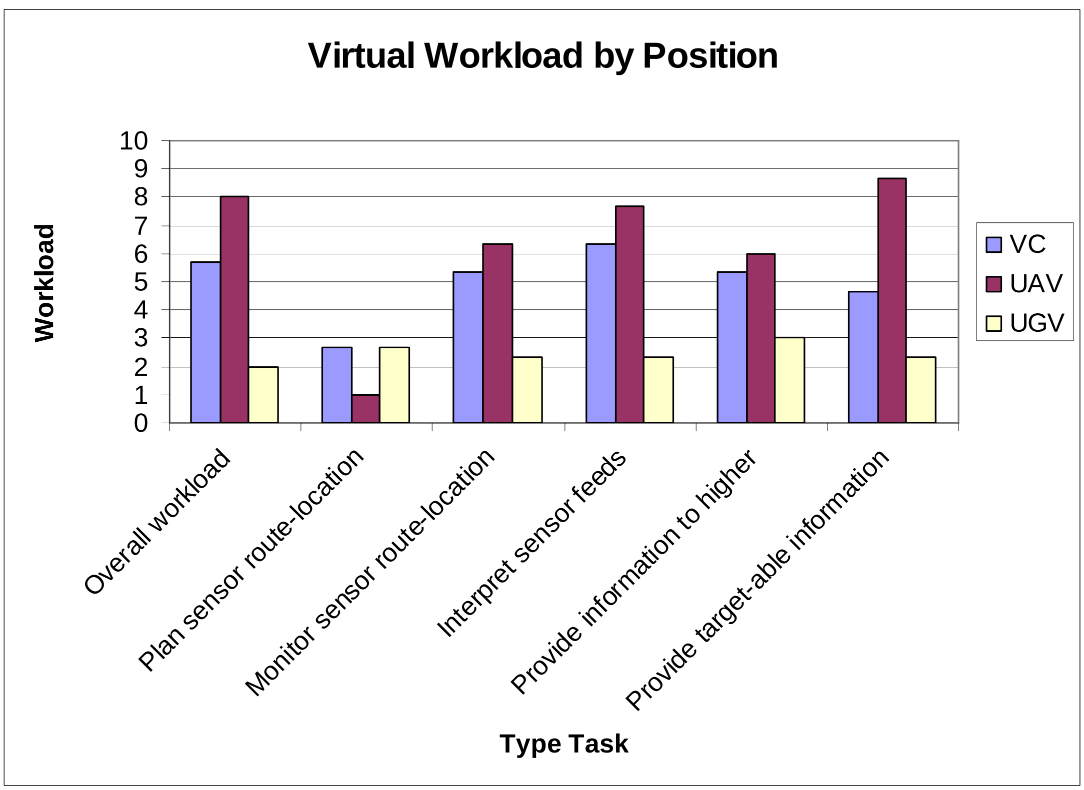

Figure 16. Virtual workload by position.

3.4.2 Stress

Data on Day 2 Missions 1 and 2 were collected on roughly comparable time periods for the live and virtual crews (missions starting about 30 minutes apart). The data in figure 17 show very similar patterns for live and virtual crews, with stress levels being somewhat higher for the virtual crew. The GSR declines slightly from baseline through Mission 1 and then increases (especially for virtual crews) through Mission 2. As was mentioned earlier, Day 2 Mission 2 was the first attempt to hold combined live–virtual missions and included technical problems. As workload was reported higher in the virtual realm for reasons previously discussed, it makes sense that stress (as measured by GSR) was somewhat higher as well.

Figure 18 shows that for virtual crew positions, as for live crews, GSR peaked during and after Day 2 Mission 2, possibly for reasons discussed before. Unlike the live crews, GSR was highest for the UAV and UGV operators and lowest for the VCs. This does not parallel the workload data for the virtual VCs, who reported higher workload than the UGV operators. Perhaps although the workload was not high for UGV operators, the stress of trying to identify a few targets through relatively poor simulated optics and plotting icons on the map was relatively high.

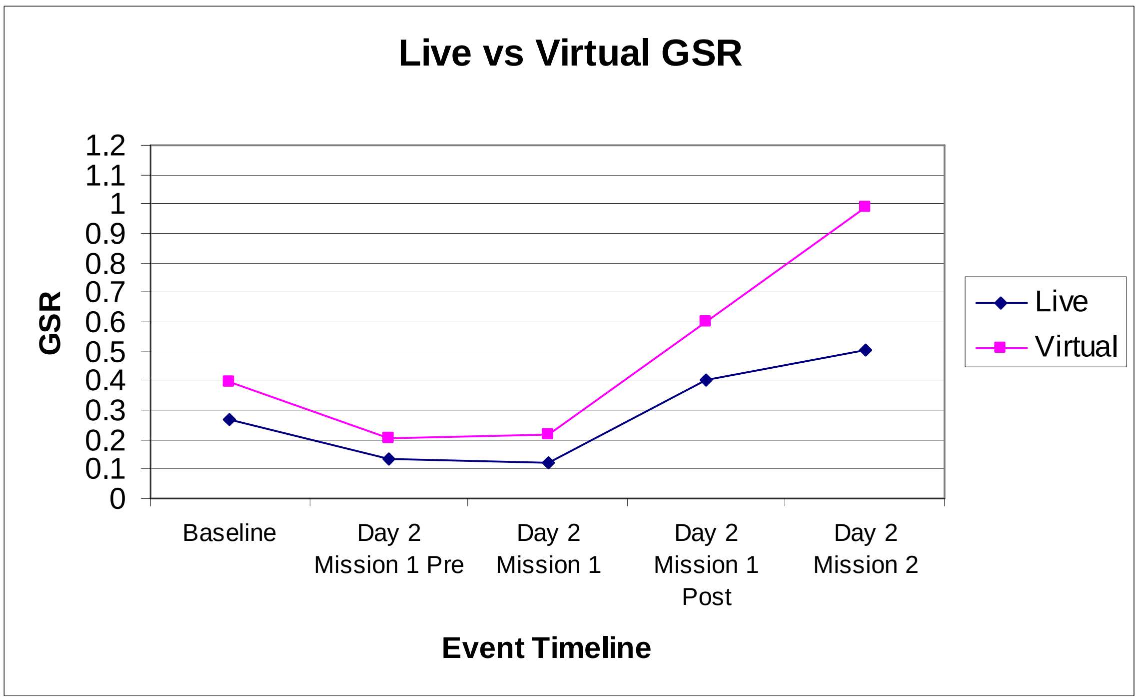

Figure 17. Live versus virtual GSR.

Figure 19 shows that unlike skin temperature for the live crew, skin temperature for the virtual crew did not resemble GSR patterns at all, being essentially flat over the course measurement. More clearly than data for the live crew, this demonstrates that environmental factors did not determine GSR levels. It makes sense that the relationship between skin temperature and GSR for the virtual crew is weaker than it is for the live crew, since the virtual crew was in a rather large air-conditioned building, essentially unaffected by ambient temperature.

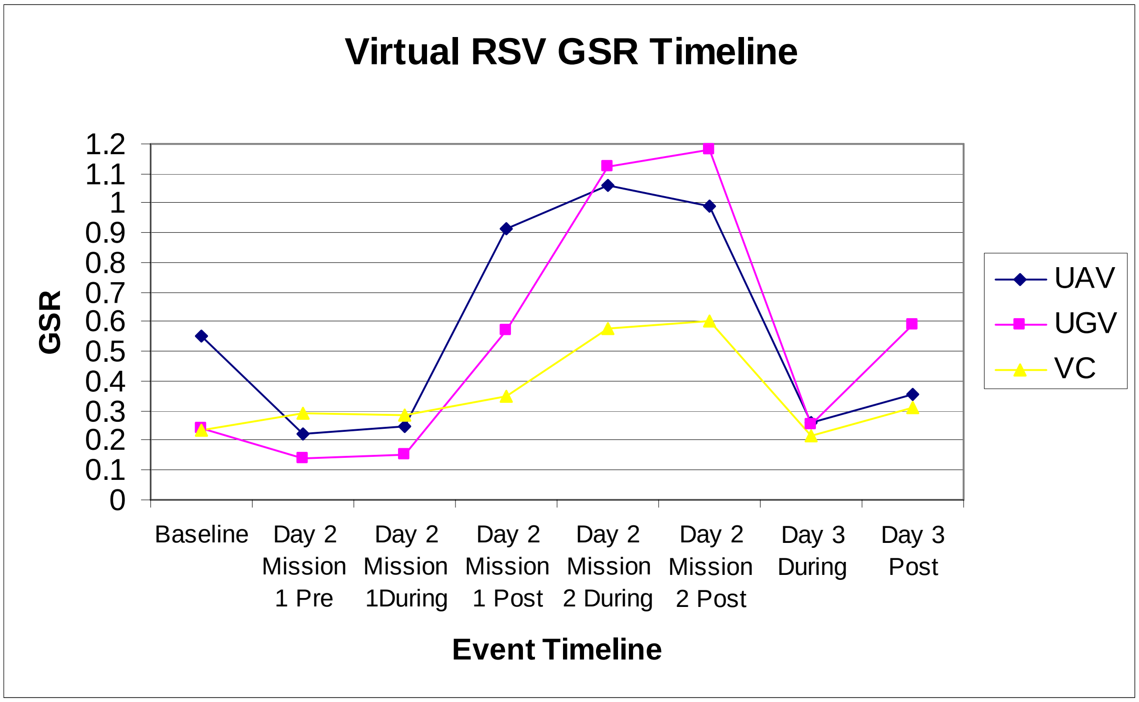

Figure 18. Virtual RSV GSR timeline.

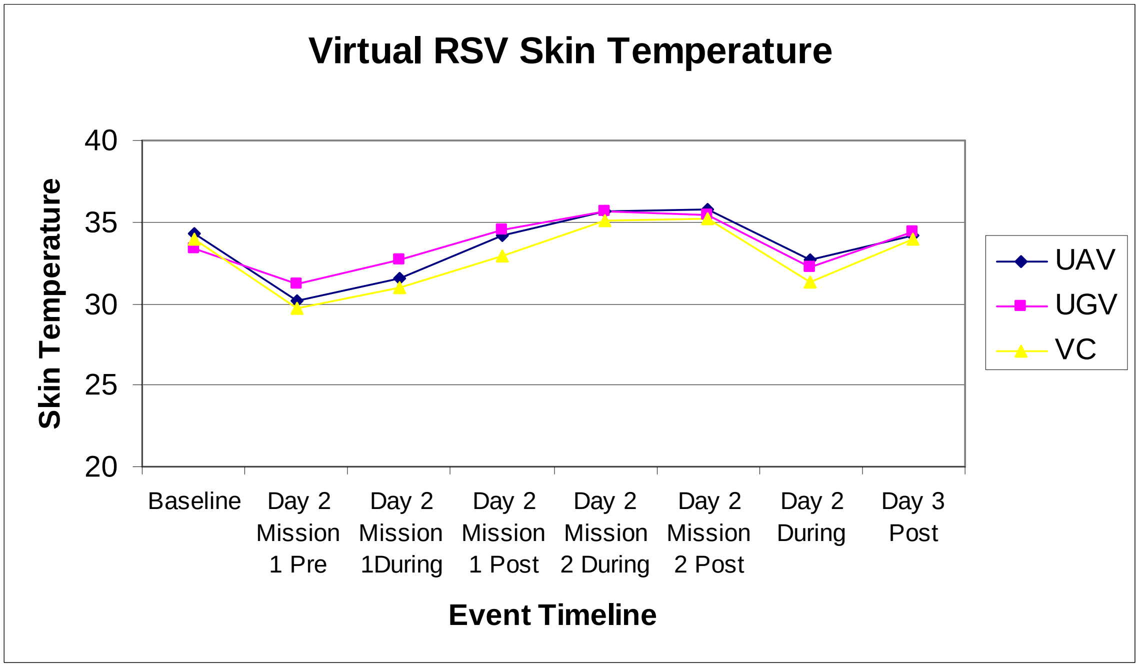

Figure 19. Virtual RSV skin temperature.

3.4.3 Situational Awareness

As shown in figure 20, SA was low and comparable for the live and virtual crews. Total SA barely exceeded 20% of the possible SA score for live and virtual crews. As discussed previously, this could be accounted for in the live crews by only one UAV flying (usually with an IR camera), the difficulty of re-tasking the UAV to identify targets, problems with the UGV, and the UGS having no cameras. For the virtual crews, there were difficulties in the quality of sensor imagery, plotting targets, and sending of multiple (redundant) spot reports.

In figure 21, unlike the live crew, the level of SA for virtual crews was far better for the VC and UGV operator than the UAV operator, for whom SA approached zero. The problems cited for the UAV operator must have been quite serious and distracting. Again, SA for the VC was slightly better for location and activity than for description, probably because of the type of information provided by the UGS.

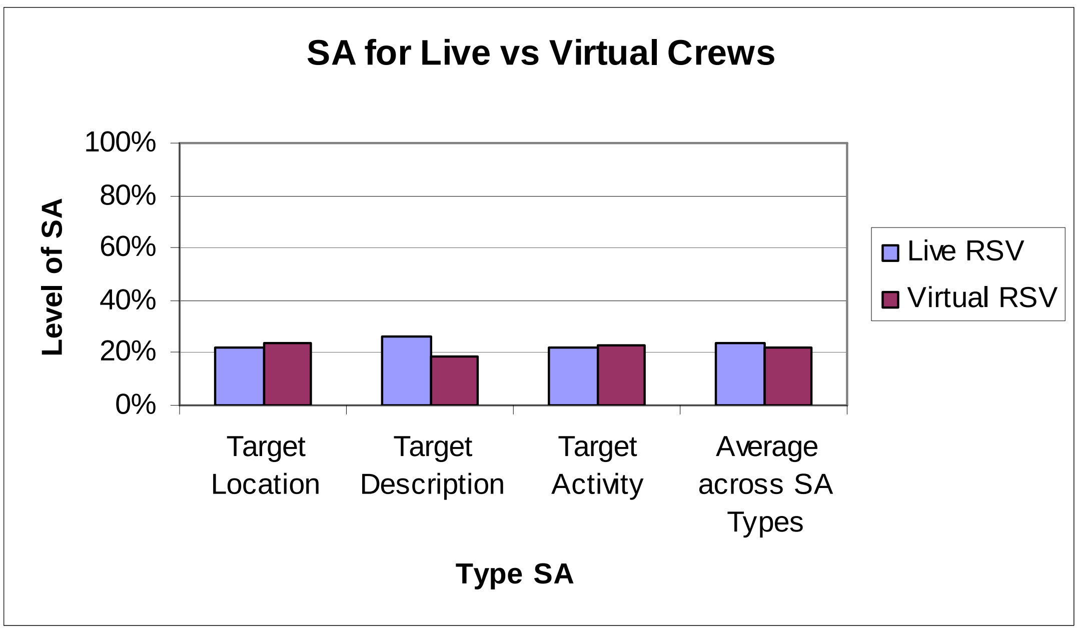

Figure 20. SA for virtual crews.

3.4.4 Realism

In appendix M, table M-11, most respondents found combined live and virtual operations realistic for sharing information and coordinating actions. However, there was a lack of consensus concerning the realism of conducting any type of reconnaissance with live and virtual wingmen. One respondent stated that he did not have a good feel as to where the other RSVs were located. Another commented that it is not possible to share the same terrain between live and virtual. Finally, another respondent indicated that except for the weather, the live and virtual worlds were the same and that interaction between live and virtual wingmen was very realistic.

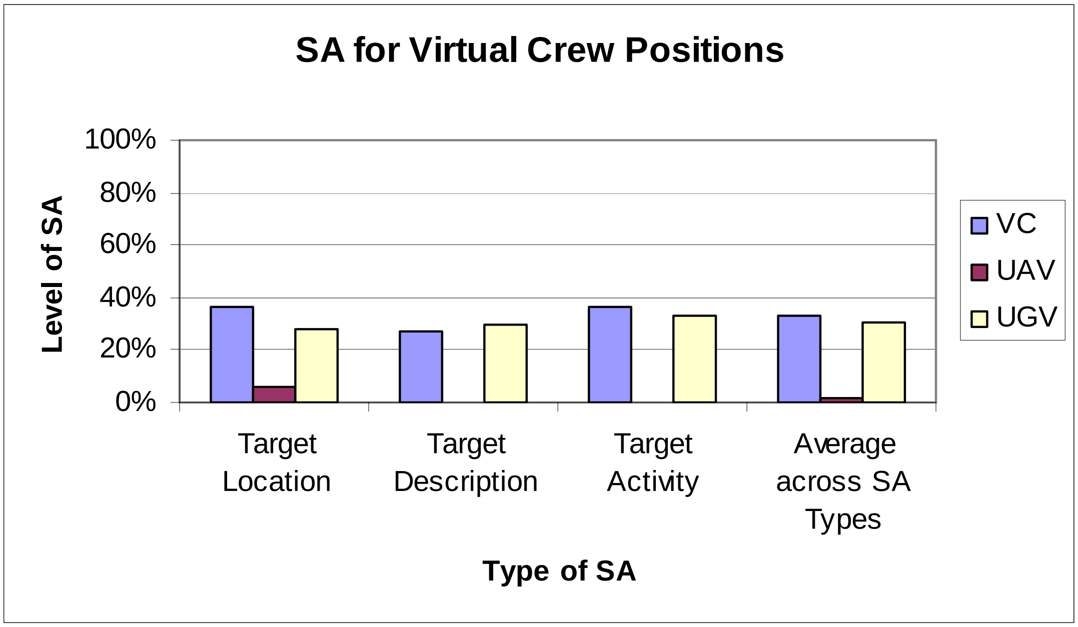

Figure 21. SA for virtual crew positions.

3.4.5 Skills Needed

Figure 22 shows that the most noticeable difference between operating sensors in live versus virtual mode was that the need for the physical skill clusters (*vision, audition, psychomotor, and gross motor*) was rated slightly higher in virtual than in live mode. The only two skill clusters rated over the mid-point of the scale (3.5) for the virtual mode were *conceptual* and *vision*. In virtual mode, operators had to manually place icons representing the enemy on the map, versus having this automatically plotted as was the case in the live mode. This could result in a greater need for *vision* to determine from the sensor feed where the enemy was located and plot it to the MC2 map. Furthermore, a greater need for *psychomotor* skills may be needed for actually locating the icon on the map in virtual mode. As with operating sensors in the RSV, the *speed loaded* and *communication* clusters were also rated above 3.0. Lesser amounts of *reasoning, audition, psychomotor* and *gross motor* skills were needed, but as stated before, more of the physical skills were needed in the virtual mode.

As shown in figure 23, in the virtual mode, the UAV operators generally reported the most need for all skill clusters with the exception of *psychomotor*. The UGV operators' reported scores reflect the next highest in need for all skill clusters, with the exception of *communications* and *psychomotor*, where the VC was second highest. During the final AAR, the UAV operators spoke the most about the differences between live and virtual, focusing on the workload involved in identifying imagery, plotting it on the display, and reporting their sensor findings.

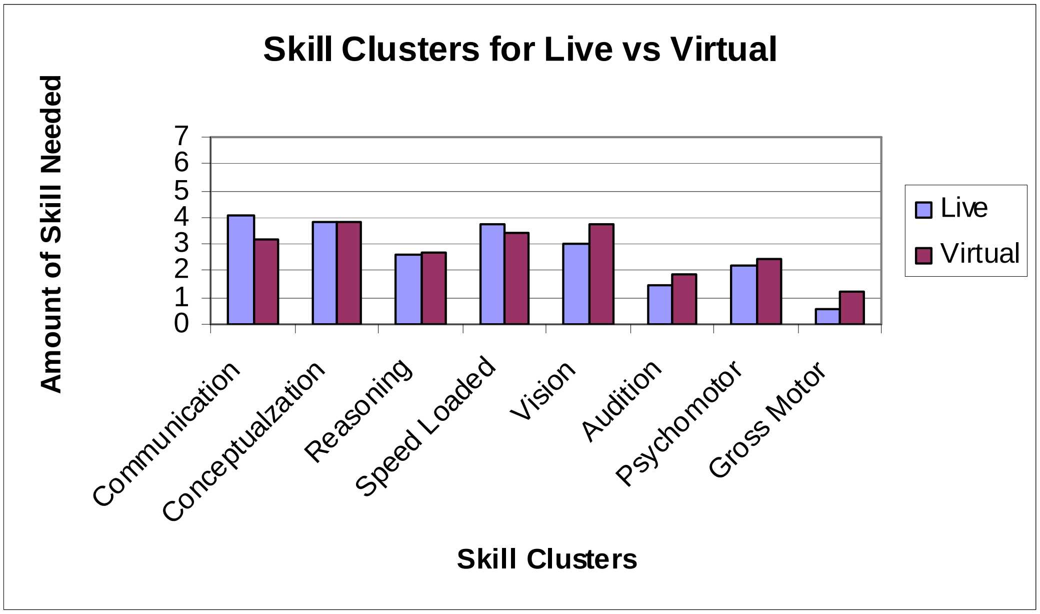

Figure 22. Skill clusters for live versus virtual.

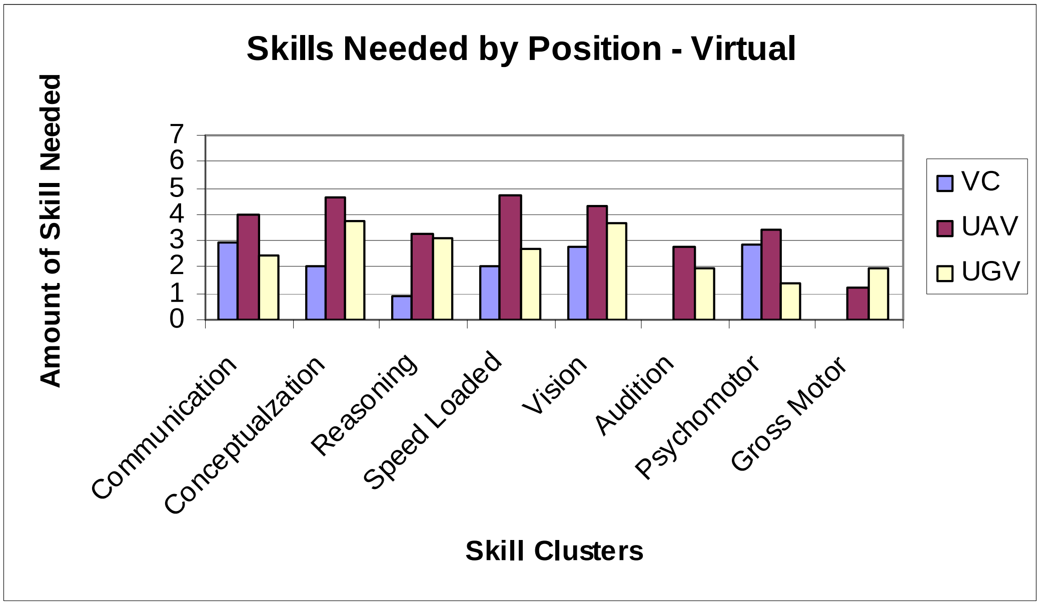

Figure 23. Skills needed by position – virtual.

3.5 Objective 4: Training on MC2 and UMS

3.5.1 Training on MC2

Figure 24 summarizes Soldier ratings on MC2 training. While most Soldiers felt that the classroom training taught them about MC2 features and capabilities and how to use them, only a slim majority felt that the training provided enough information for them to be able to perform their test duties using MC2. Oddly enough, a large majority of the Soldiers felt that the training gave them the confidence to perform their test duties using MC2. A review of the comments suggests that the MC2 training provided Soldiers with enough information to understand how to perform their test duties but the hands-on activities that were undertaken during test execution presented some challenges to Soldiers. The tools used during training appeared to be slightly different, as indicated by a UGS operator, and the operators likely needed “time in the saddle”. One Soldier indicated that he required additional sidebar help simply for “familiarization”. Some test participants indicated that the difference in the training and the test environments presented challenges such as changes in sequences of operation and “task degradation”. Some Soldiers indicated that more training was needed on the graphic features associated with MC2. It was also noted that the time between classroom training and actual test execution was too long (more than 1 day) and Soldiers suggested that classroom to hands-on training be scheduled so that there is no more than a 1-day separation. Overall, most Soldiers indicated that while the training was enough to perform their test duties, a more extensive and comprehensive training program would be needed to achieve and maintain proficiency with MC2.

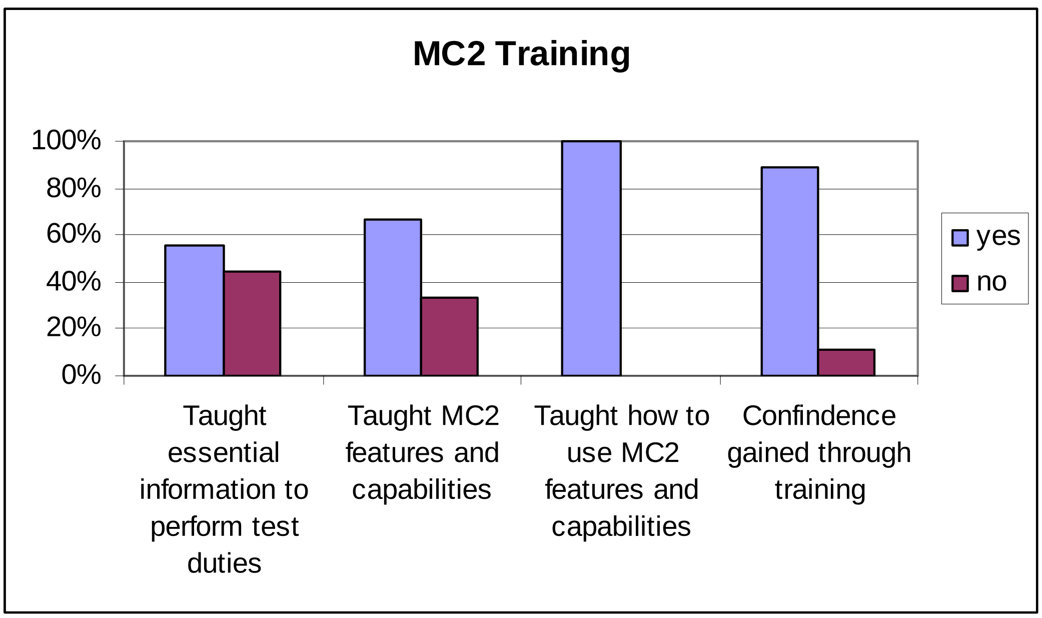

Figure 24. Training on MC2.

3.5.2 Training on UMS

Figure 25 summarizes survey data on UMS training. Response rates are generally the same across all survey items. Most Soldiers reported that sufficient training was provided in terms of knowing and using the features and capabilities of the UMS. Most Soldiers, however, also noted that they required additional sidebar training once they moved from the training environment to test execution. Soldier comments suggest that more time for familiarization and hands-on practice using the UMS is needed and that confidence will grow as more time is taken to work with the system. Several comments addressed the need for training to introduce re-tasking of the unmanned assets into the program of instruction. This was mentioned by UAV as well as UGV operators.

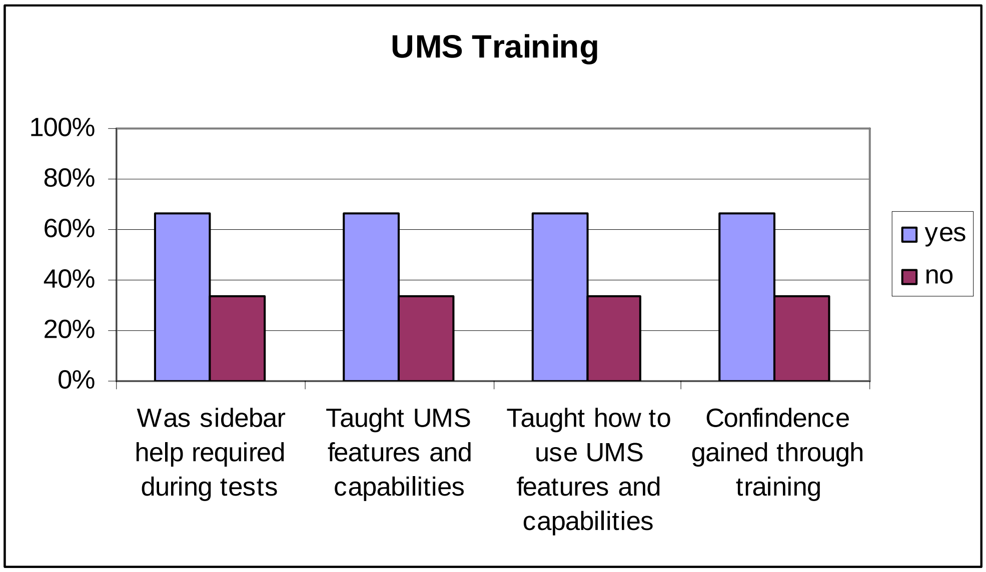

Figure 25. Training on UMS.

3.5.3 Combined MC2 and UMS Training

Figure 26 illustrates the responses for survey items regarding applied training for the MC2 and UMS together. When asked whether they felt that the training taught them how to use MC2 and UMS combined, 78% of the Soldiers responded positively while 22% indicated that they did not receive adequate combined applied training. Soldier comments suggest that hands-on experience and high fidelity simulation are essential to providing the training needed to conduct tasks using MC2 and UMS together.

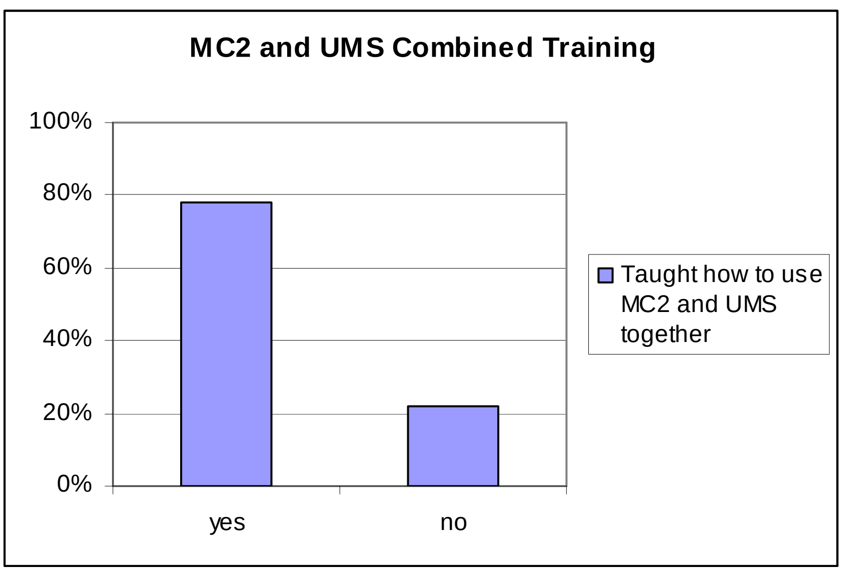

Figure 26. Combined MC2 and UMS training.

4. Discussion

4.1 Objective 1: How the Use of Unmanned Reconnaissance Assets Affects Soldier Performance (live RSV)

Overall, workload and SA were low for scouts using robotic sensors. The area covered by sensors was seen as greater for scouts using sensors versus manned reconnaissance. Speed of reconnaissance using sensors was judged as faster for planning but not for execution. Survivability with sensors was judged as the same or worse than manned reconnaissance. The most necessary skills needed are communication, problem solving, and target recognition.

The levels of Soldier workload and SA were low in this demonstration for live sensor operators. There were several reasons (cited previously) for this. While some of the reasons point to technical deficiencies in the setup of the experiment, others suggest that sensor software capabilities and features of the user interface may impact Soldier workload and level of SA. Experimental limitations consisted of generally only one UAV flying at a time, and that UAV having only an IR camera that did not work well for identifying targets during daylight, resulting in few targets being identified. Also, the UGV often lost connectivity, and even when usable, could provide no pictures when moving. Perhaps this is why the UGV operator had the lowest SA. Furthermore, the UGS did not have working cameras and therefore was limited to simply detecting a target at best. Both the UAV and UGV were difficult to re-task; thus, targets detected by one sensor (e.g., the UGS) could not be quickly identified by another before moving.

In general, the area covered by networked sensors was judged to be greater than by dismounted scouts. The UGS could detect targets in a wide area and never get tired or inattentive as could a dismounted Soldier. The UAV had the capability to fly over a large area in relatively little time. The UGV, if overlooking an area from an elevated position, could provide high quality snapshots that covered a wide area, again without becoming inattentive.

Overall, the speed of reconnaissance was judged as faster for planning and deploying assets but slower for completing missions. The planning was fast and easy in MC2, and the deployment of the UAV was relatively fast as well. The UGS was deployed by technicians before missions were started, so that may have contributed to the Soldiers' perceptions of speedy deployment of assets. Regarding the speed of completing reconnaissance missions, however, comments suggested that the technical problems with the sensors and their control contributed to less than positive views.

Soldiers generally felt that the survivability of the unmanned sensors was the same or worse than current scout assets used to perform the same tasks. The RSV was much lighter than the assets with which most of these personnel were experienced, such as Bradley scout vehicles or M1A1 tanks. Based on their reports of limited SA in this demonstration, Soldiers conceivably felt that the ability to identify and destroy the threat before being detected and destroyed by the threat (the main advantage of this type of asset) was questionable. After all, target acquisition was generally limited to detection of targets. The capability for classification, recognition, or identification needed to provide target-able information was not there for Soldiers in this demonstration. This perhaps led to the assessment of poor survivability of the unmanned sensors.

Results from the JASS survey indicate that overall, operators of unmanned sensors require skills that are necessary to receive information from and send information to higher echelons (*communication*), identify and solve problems concerning sensor coverage (*conceptual*), and recognize targets quickly (*speed loaded*). It appears that *visual* skills are also needed to interpret sensor feeds and track the sensor on the MC2.

4.2 Objective 2: Assessment of the Soldier-Machine Interface

Overall, while mission planning tools were evaluated highly, mission execution tools and sensor image quality were seen as lacking.

Mission planning in MC2 was very easy and the tools available were good. However, altering initial plans, which involves re-tasking, took too long; routes had to be completely re-drawn, and even changing the altitude of the UAV was not easy. Also, when re-tasking was accomplished on the MC2, it seemed to take a long time for the re-tasking to reach to the sensor in order to actually alter the route of the sensor. Since detected targets were potentially always moving, by the time the sensor was able to return after a re-task, the targets often were no longer in the area. Thus the search started anew. However, if target-able information were available, sending spot reports would be easy.

The quality of the sensor imagery was problematic. The infrared camera in the UAV was not good enough to identify a target. It could detect a “blob” but needed another sensor (e.g., UGV or UAV with daylight camera) to identify it and to provide target-able information. Also, the only way to control the angle of the camera was to control the position of the sensor.

An ability to control multiple sensors via an effective interface tool was deemed vital. Moreover, features that enabled operators to provide target identification, location, and spot reports to higher echelons were also critical.

4.3 Objective 3: Live Versus Virtual Networked Sensors

Overall, workload and stress were higher in the virtual than live mode. The SA was equally poor for both groups, and skill clusters needed were generally comparable.

Workload was higher in the virtual versus live mode. Some of the reasons for this were that the sensor imagery was reported to be poorer in the virtual mode, and targets had to be plotted manually on the MC2 versus automatically, when a snapshot was taken in the live RSV.

Because operators were unsure whether they had seen and plotted a target at a given location, they sent multiple spot reports. The UAV operators reported the most difficulties of this type and the highest workload in virtual.

Stress, as measured by GSR, was higher in virtual, perhaps for the reasons cited before. Although stress was elevated for both groups during the first mission where "connectivity" between the live and virtual world was attempted, it was especially elevated for the virtual group.

SA was equally poor for both groups, but especially so for the UAV operator in virtual and UGV operator in live. Perhaps SA was unduly affected by technical difficulties such as lack of a second UAV or daylight camera on the one UAV flying, loss of connectivity for the UGV, or a lack of cameras on the UGS.

Skill clusters needed were similar in live and virtual, with a slightly higher need for physical skills such as vision and psychomotor in virtual because of the poorer imagery and need to manually plot targets. Both environments had a need for skills necessary to receive information from and send information to higher echelons (*communication*), identify and solve problems concerning sensor coverage (*conceptual*), and recognize targets quickly (*speed loaded*).

4.4 Objective 4: Training

Overall, it appears that training was tailored for this demonstration only, both in terms of time allocated and training content. Soldiers appear to have been given the essentials to begin their roles as sensor operators, but comments and ratings suggest that more classroom instruction as well as hands-on training would be needed for a Soldier to effectively and confidently assume the official role of a sensor operator. Many features of the MC2 and UMSC were presented to the Soldiers in this demonstration, but little time was provided for using those features during tasks until the experiment was actually under way. Soldier comments, however, are informative in that they stress the need for high fidelity and hands-on training to gain the expertise and confidence needed to operate unmanned sensors.

5. Conclusion

It seems that the promise of networked sensors was not fully demonstrated because of technical difficulties and that changes in the virtual environment need to be made to make it more comparable to the live environment. Also, the limited high fidelity and hands-on training may have hampered the effective use of sensors. While important interface features and training needs were revealed, further evaluation is warranted.

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Appendix A. MC2 and UMS Interface Description

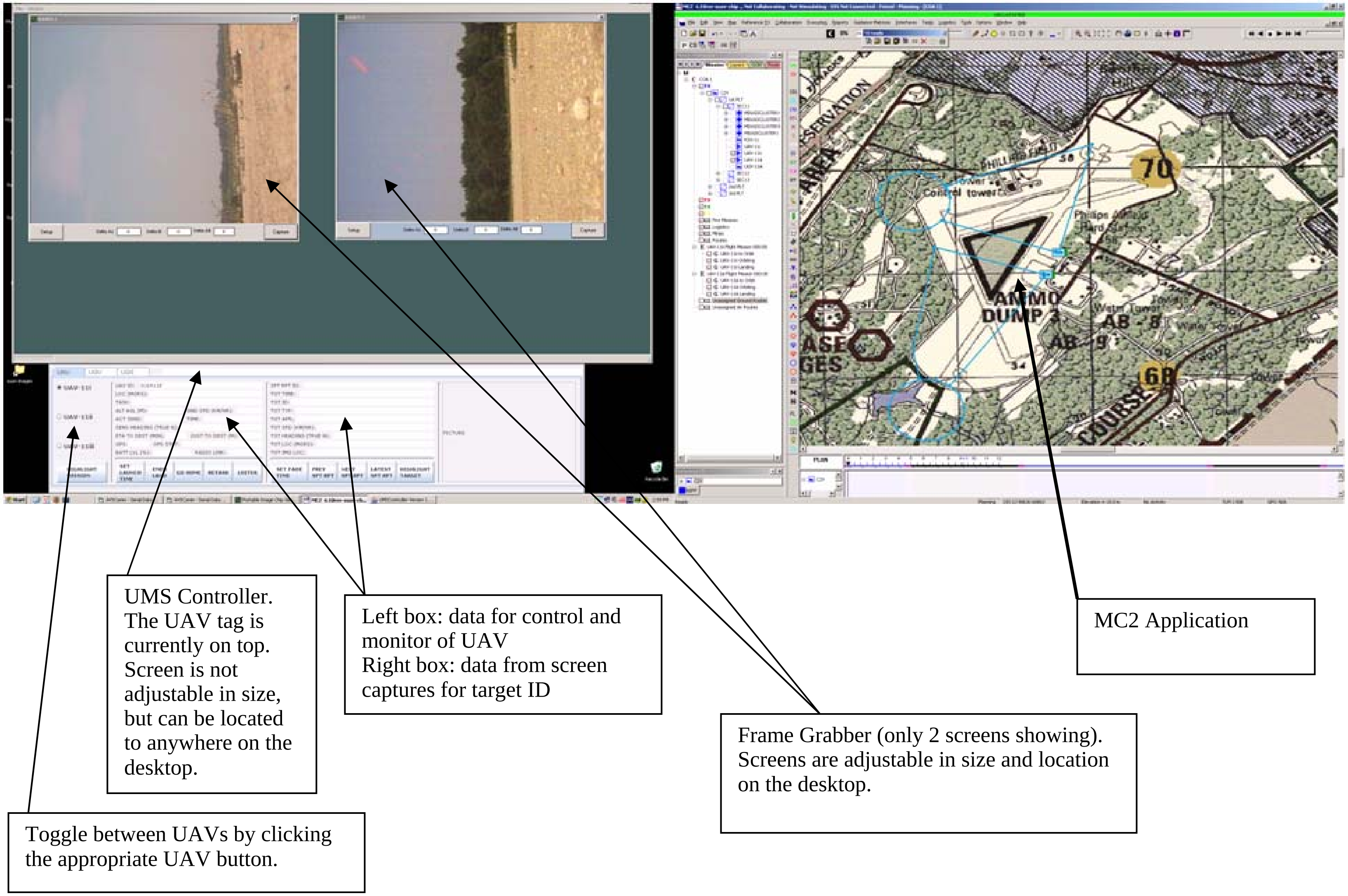
The OCUs for the UAV, UGV and UGS consisted of two full-size display screens mounted on a swivel post. A keyboard was located directly below the left display screen. The mouse consisted of a trackball incorporated into the keyboard. A stylus was not incorporated into the setup, per design. The following pictures illustrate the left and right display screens.

A. Left Display Screen. The left display screen allows both touch screen and keyboard/ trackball input. Two applications are based in the left display screen:

Portable Image Chip Generator (colloquially, the *frame grabber*). This application allows the user to view live video feed from the UAV's camera with as many as three screen boxes. The frame grabber provides streaming video from UAVs only; the UGS and UGV frame grabber provides only static pictures. The screen boxes are adjustable in size, shape, and location on the desktop. It was suggested by a SME designated for this experiment that a stylus is available in order to mark precisely on the screen box when one is making screen captures. Currently, Soldiers must use their fingers to select points on the screen. Once a screen capture is made, a second display box pops up and shows the image surrounding the point chosen for screen capture. Furthermore, data fields in the UMS controller will automatically become populated with information on the screen capture. This capability was not demonstrated during the site visit but it is the intention of the developers. The display boxes for the live video feed and screen captures are very similar and can become confusing.

UMS Controller. The UMS provides the OCU operator with information to monitor the UAV and provides data on screen captures made from the frame grabber. The UMS screen box can be moved anywhere on the desktop, but the size and shape are not adjustable. The UMS controller has three tabs, one for each unmanned asset type (UAV, UGV, and UGS). On the UAV tab, three UAVs can be controlled, and switching between each screen is accomplished via a toggle method.

B. Right Display Screen. The right display screen consists of the MC2 application and receives input from only the keyboard and trackball. MC2 has been assessed previously although assessment of the MC2 during the Networked Sensors demonstration will focus on features of the application that are specific to the tasks of the OCU operator. The OCU operator uses the MC2 application for route planning, creating and executing missions of unmanned assets.



The picture above is a screen capture that combines the left and right display screens for the OCU operator. This figure represents the set up for all unmanned assets, and the UMS controller is currently showing the UAV tag.

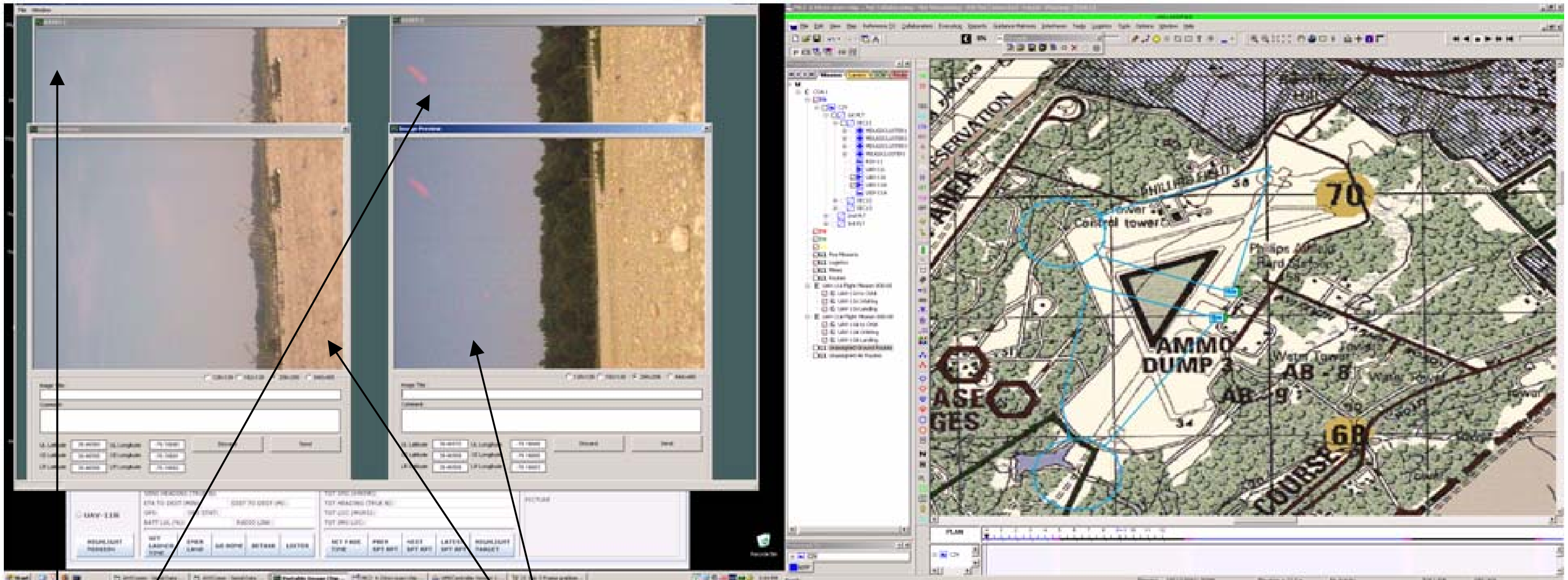


Image captures from the frame grabber box screens.

Frame grabber box screens

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Appendix B. Assessment of Workload

Assessment of Workload. (addresses EEA 3.5) Rate the workload of the following tasks on the following scale

Task	**Workload Insignificant** (1)	**Workloa d Low** (2)	**Enough spare capacity** for all desirable additional tasks (3)	**Insufficient spare capacity** for easy attention to additional tasks (4)	**Reduced spare capacity** additional tasks cannot be given the desired amount of attention (5)	**Little spare capacity** Level of effort allows little attention to additional tasks (6)	**Very little spare capacity** but maintenance of effort in the primary task is not in question (7)	**Very high workload with almost no spare capacity** difficulty in maintaining level of effort (8)	**Extremely high workload** no spare capacity and difficulty in maintaining level of effort (9)	**Task abandoned** unable to apply sufficient effort (10)
a. Overall workload										
b. Plan sensor route or location										
c. Monitor sensor route or location										
d. Interpret sensor feeds										
e. Provide information to higher										
f. Provide target-able information										

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Appendix C. JASS Skill Clusters

COGNITIVE SKILL AND EXPERIENCE CLUSTERS		**PERCEPTUAL-MOTOR ABILITY CLUSTERS**	
Communications	Conceptual	Vision	Audition
1. Oral Comprehension	5. Memorization	24. Near Vision	31. General Hearing
2. Written Comprehension	6. Problem Sensitivity	25. Far Vision	32. Auditory Attention
3. Oral Expression	7. Originality	26. Night Vision	33. Sound Localization
4. Written Expression	8. Fluency of Ideas	27. Visual Color Discrimination	
	9. Flexibility of Closure	28. Peripheral Vision	
	10. Selective Attention	29. Depth Perception	
	11. Spatial Orientation	30. Glare Sensitivity	
	12. Visualization		
<u>Reasoning</u>	<u>Speed-Loaded</u>	<u>Psychomotor</u>	<u>Gross Motor</u>
13. Inductive Reasoning	19. Time Sharing	34. Control Precision	41. Extent Flexibility
14. Category Flexibility	20. Speed of Closure	35. Rate Control	42. Dynamic Flexibility
15. Deductive Reasoning	21. Perceptual Speed / Accuracy	36. Wrist-Finger Speed	43. Speed of Limb Movement
16. Information Ordering	22. Reaction Time	37. Finger Dexterity	44. Gross Body Equilibrium
17. Mathematical Reasoning	23. Choice Reaction Time	38. Manual Dexterity	45. Gross Body Coordination
18. Number Facility		39. Arm-Hand Steadiness	46. Static Strength
		40. Multi-Limb Coordination	47. Explosive Strength
			48. Dynamic Strength
			49. Trunk Strength
			50. Stamina

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Appendix D. Situational Awareness

Date: (dd:mm:yy) __ __:__ __:__ __ Time: (24-hour time to minute) ___ ___ ____ ____

PIN ___________

1. Position (Check one)
___ Troop Commander
___ Platoon Leader
___ Vehicle Commander (Chief Scout in Vehicle)
___ UAV Operations
___ UGV Operations

2. Vehicle (Check one)
___ Troop Commander Vehicle
___ Live RSV (Platoon Leader Vehicle)
___ Wingman 1 (Virtual ACRT)
___ Wingman 2 (Virtual ACRT)

Instructions for UAV Operations or UGV Operations personnel:
Indicate on the map provided the location of OPFOR entities that you have identified **in your vehicle's area of operation**. Then label each with a number from 1 to N. If more than one entity is located at the same approximate location, you can label them all with the same number. Then answer the questions in the columns labeled "Description," "Current Activity," and "Future Location" in the following table for each of the numbers that you have assigned. Do not write in the columns with grayed-in titles.

Instructions for Vehicle Commanders and Platoon Leader:
Indicate on the map provided the location of OPFOR entities that you have identified **in the entire platoon's area of operation**. Then label each with a number from 1 to N. If more than one entity is located at the same approximate location, you can label them all with the same number. Then answer the questions in the columns labeled "Description," "Current Activity," and "Future Location" in the following table for each of the numbers that you have assigned. Do not write in the columns with grayed-in titles.

SA Table

Number (matching location on map)	**Location Score (Perception)**	**Description (e.g., enemy tank, Platoon leader's vehicle)**	**Comprehension Score (0,1,2)**	**Current Activity (e.g., moving west, stationary)**	**Comprehension Score (0,1,2)**
1					
2					
3					
4					
5					

Number (matching location on map)	**Location Score (Perception)**	**Description (e.g., enemy tank, Platoon leader's vehicle)**	**Comprehension Score (0,1,2)**	**Current Activity (e.g., moving west, stationary)**	**Comprehension Score (0,1,2)**
6					
7					
8					
9					
10					

Number (matching location on map)	Location Score (Perception)	Description (e.g., enemy tank, Platoon leader's vehicle)	Comprehension Score (0,1,2)	Current Activity (e.g., moving west, stationary)	Comprehension Score (0,1,2)
11					
12					
13					
14					
15					

Appendix E. Networked Sensors Questionnaire

1. Position (Check one): Date: (dd:mm:yy) __ __:__ __:__ __

___ Troop Commander
___ Platoon Leader
___ Chief Scout in Vehicle
__ UAV Operations
___ UGV Operations

2. PIN_______________

3. Assessment of Zone Coverage: (addresses EEA 3.2) The following scenario applies to these questions on zone reconnaissance. Your platoon conducts zone reconnaissance east to 31W between Ft Knox/Vine Grove Road on the south, Highway 60 center, to Ohio River (8201) on the north. Your mission is to locate and destroy by indirect fires enemy screening elements. You must establish a screen along Ft Knox/Vine Grove Road to provide early warning to CAB of enemy forces that may maneuver west of 31 W attempting to use Brandenburg Bridge. On order you must establish OP's over-watching 31W and bridges over Salt River to coordinate Joint Fires on fleeing enemy along 31W.

For this question, zone coverage is defined as identifying all tactically significant elements in the zone. This includes all enemy forces, all partisan forces, all coalition forces, significant concentrations of civilians that could have an impact on the tactical situation (e.g., refugees or their vehicles blocking roads), terrain and infrastructure (e.g., condition of bridges).

Rate your assessment of zone coverage using the systems you worked with in this demonstration by marking an "X" in the appropriate block. Based on your knowledge of current operations, rate the change in zone coverage using the systems you worked with in this demonstration on the following scale.

Question	Much Smaller	Smaller	Same	Larger	Much Larger	Don’t Know
a. Width of zone that can be effectively covered						
b. Depth of zone that can be effectively covered						
c. Overall area of zone that may be effectively covered						
d. Overall area that can be covered in terrain involved in test						
e. Overall area that you think can be covered in open terrain						
f. Overall area that you think can be covered in urban terrain						

Comments

4. Assessment of speed of reconnaissance: (addresses what EEA?) Rate your assessment of the speed of reconnaissance using the systems you worked with in this demonstration, compared to the speed of reconnaissance with current systems with which you have experience, by marking an “X” in the appropriate block. Based on your knowledge of current operations, rate the change

in speed of reconnaissance using the systems you worked with in this demonstration on the following scale.

Question	**Much Slower**	**Slower**	**Same**	**Faster**	**Much Faster**	**Don't Know**
a. Speed of developing a plan, including reconnaissance routes for UAVs and UGV and placement of UGS						
a. Speed of deploying reconnaissance assets (time from when plan is developed until UAVs and UGV begin their routes and until UGS are deployed)						
b. Speed of completing route reconnaissance (all tactically significant aspects of the route are identified)						
c. Speed of completing area reconnaissance (all tactically significant aspects of the area are identified)						
d. Speed of completing zone reconnaissance (all tactically significant aspects of the zone are identified)						

Describe the current systems with which you have reconnaissance experience (for example HMWWV with LRAS and FBCB2)

Comments on speed of reconnaissance with sensors

5. Assessment of survivability of manned reconnaissance platforms: (addresses EEA 3.3) For items a to c survivability is defined as the manned platform not being detected by the enemy. For items d to h, survivability is defined as the manned platform not being detected by the enemy at a range in which it could be effectively engaged.

Rate your assessment of the survivability of manned reconnaissance platforms using the systems you worked with in this demonstration by marking an “X” in the appropriate block. Based on your knowledge of current operations, rate the change in survivability of manned reconnaissance platforms using the systems you worked with in this demonstration.

Question	**Much Less Survivable**	**Less survivable**	**Same**	**More Survivable**	**Much More Survivable**	**Don’t Know**
a. Conducting route reconnaissance						
b. Conducting area reconnaissance						
c. Conducting zone reconnaissance						
d. Threat with small arms						
e. Threat with RPG						
g. Threat with IED						
f. Threat with armored vehicle						
g. Threat with mortar						
h. Threat with artillery						

Comments

6. Context provided by additional simulated forces: (addresses EEA 5.3) Compared to having “live” platforms for wingmen, rate the realism of having the “virtual” platforms for wingmen.

Question	**Very Unrealistic**	**Unrealistic**	**Borderline**	**Realistic**	**Very Realistic**	**Don’t Know**
a. Providing information to wingmen						
b. Acquiring information from wingmen						
c. Coordinating actions with wingmen						
d. Having a common operational picture with wingmen						
e. Conducting route reconnaissance with wingmen						
f. Conducting area reconnaissance with wingmen						
g. Conducting zone reconnaissance with wingmen						

Comments

7. Effectiveness of unmanned screen to the flank: (addresses what EEA? 3.1, 3.2) When conducting a screen to the flank, rate the ability to use the unmanned sensors available to you during the demonstration to detect the following types of assets infiltrating the area. In the following questions, the terms detect, classify, recognize, and identify are defined as follows:

- Detect = Determine something of military significance is present
- Classify = Determine class of entity (e.g., wheeled versus tracked vehicle)
- Recognize = Determine general type of entity within a class (e.g., tank versus tracked APC)
- Identify = Determine specific model of entity (e.g., T-80 tank, Bradley Fighting Vehicle)

Question	**Very Poor**	**Poor**	**Borderline**	**Good**	**Very Good**	**Don't Know**
a. Ability to detect dismounts						
b. Ability to detect wheeled vehicles						
c. Ability to detect tracked vehicles						
d. Ability to detect squad sized entities						
e. Ability to detect platoon size entities (generalize based on your experience in this demonstration)						
f. Ability to detect company sized entities (generalize based on your experience in this demonstration)						

Comments

8. Ability of sensors to provide target-able data: (addresses EEA 3.4) Rate the ability of the sensors to provide the following type of information on the following scale.

Question	**Very Poor**	**Poor**	**Borderline**	**Good**	**Very Good**	**Don't Know**
a. Ability to detect dismounted entities						
b. Ability to classify dismounted entities						
c. Ability to recognize dismounted entities						
d. Ability to identify dismounted entities						
e. Ability to provide accurate target location on dismounted entities						
f. Ability to provide timely information on dismounted entities						
g. Ability to detect wheeled entities						
h. Ability to classify wheeled entities						
i. Ability to recognize wheeled entities						
j. Ability to identify wheeled entities						
k. Ability to provide accurate target location on wheeled entities						
l. Ability to provide timely information on wheeled entities						
m. Ability to detect tracked entities						
n. Ability to classify tracked entities						
o. Ability to recognize tracked entities						
p. Ability to identify tracked entities						
q. Ability to provide accurate target location on tracked entities						
r. Ability to provide timely information on tracked entities						
s. Ability to detect potential IEDs						
t. Ability to classify potential IEDs						
u. Ability to recognize potential IEDs						
v. Ability to identify potential IEDs						
w. Ability to provide accurate target location on potential IEDs						
x. Ability to provide timely information on potential IEDs						

Comments

9. Assessment of workload. (addresses EEA 3.5) Rate the workload of the following tasks on the following scale

Task	**Workload Insignificant** (1)	**Workload Low** (2)	**Enough spare capacity** for all desirable additional tasks (3)	**Insufficient spare capacity** for easy attention to additional tasks (4)	**Reduced spare capacity** additional tasks cannot be given the desired amount of attention (5)	**Little spare capacity** Level of effort allows little attention to additional tasks (6)	**Very little spare capacity** but maintenance of effort in the primary task is not in question (7)	**Very high workload with almost no spare capacity** difficulty in maintaining level of effort (8)	**Extremely high workload** no spare capacity and difficulty in maintaining level of effort (9)	**Task abandoned** unable to apply sufficient effort (10)
a. Overall workload										
b. Plan sensor route or location										
c. Monitor sensor route or location										
d. Interpret sensor feeds										
e. Provide information to higher										
f. Provide target-able information										

10. Assessment of utility of planning tools in developing a sensor employment plan: (addresses EEA 3.6) Using the scale below, rate the utility of the following MC2 features or tools in developing a sensor employment plan.

Question	**Very Poor**	**Poor**	**Borderline**	**Good**	**Very Good**	**Don't Know**
a. Select new course of action						
b. Select TDA						
c. Select map						
d. Zoom in and out on map						
e. Draw area of coverage						
f. Plan UAV route(s)						
g. Line of sight tool						
h. Distance tool						
i. Friendly direct fire fans						
j. Enemy direct fire fans						
K Enemy ADA circles						
l. Intervisibility plot						
m. Elevation plot						
n. Mobility plot						
o. Sensor coverage plot						
p. Plan view						
q. Blue plan-current situation view						
r. All plan-current situation view						

Comments

Participant Comments on Networked Sensors Questionnaire

UAV – Unmanned Arial Vehicle operator
UGV- Unmanned Ground Vehicle operator
CSV- Chief Scout in Vehicle
PL- Platoon Leader
TC- Troop Commander

Question 3. Assessment of zone coverage.

- UAV- No identification can be done with UAV, only detection.
- UAV- The UAV is effective at detecting, but not developing, situations. It notifies the crew of the enemy forces that are in the sector and it shows us where but as far as what the enemy actions are, it is difficult to assess. By the time the UAV is re-tasked to an area the enemy has shifted. In the real world enemy units can just move into dense vegetation and the UAV will be useless. Ned a helicopter type UAV.
- UGV- Using UAV [or] UGV depends on terrain *(reference to item a)*. Use UAV [and] UGV for [the] desert *(reference item b)*. Depends on what is being covered, better for UAV *(reference item c)*. [There is] more dead space in [the] woodland, better for UAV *(reference item d)*. Open is better for UGV *(reference item e)*. [Urban terrain is] better for UAV, UGV at a distance *(reference to item f)*.
- CSV- Coverage, I think, is adequate. Information overload is a concern for me.
- PL- Need a thorough scenario (orders process) in order to properly apply the technology.
- TC- Obviously, sensors are not a “cure-all” for perfect coverage. However, all the various types of sensors have capabilities that, when used correctly, can increase coverage. Currently, no single sensor can be used in a manner which allows a leader to think he is 100% covered for a given area. However, with an understanding of the sensor limitations, a combined, synchronized plan with sensors and Soldiers can be developed to provide redundancy on key enemy avenues of approach and therefore greater coverage can be obtained with a greater chance of success. Combined with greater successful coverage, the network ability allows us to respond to threats faster at all levels and potentially bring destructive fires.

Question 4. Assessment of speed of reconnaissance.

A. Current systems with reconnaissance experience

- UAV- Did reconnaissance on M1A1; HMWWV
- UAV- HMWWV with LRAS; Dismounted with nothing but binoculars, map and a radio.
- UGV- M3A2 Bradley; HMWWV no LRAS
- UGV- HMWWV with LRAS
- CSV- HMWWV only
- PL- Dismounted
- TC- M1A2SEP; HMWWV with LRAS; M3A2 ODS; Javelin; CLU; TWS; FBCB2 (M1A2SSEP and HMWWV); BFT

B. Speed of reconnaissance.

- UAV- Have no tactical experience with UAV to compare against current systems.
- UAV- With the LRAS I can see into the area, visually clearing. The UAV can fly into dead space or ahead to clear my flanks forward of my position.
- UGV- Very good
- UGV- If equipment stays up, need more battery life for UAV *(reference item b)*. If equipment stays up, distance to be covered *(reference item c)*. If equipment stays up, if equipment understands aspects for the route *(reference item d)*.
- CSV- We could not use the sensors to their maximum capability, so my comments are pretty limited.
- PL- Sensors greatly assist with gaining an idea, however, [regarding] specific areas, routes still need to be proofed by Soldiers. Speed is a relevant term with regard to time available.

Question 5. Assessment of survivability of manned reconnaissance platforms.

- UAV- Did all reconnaissance in an M1A1 tank; I don't [think a] comparison should be made versus current force.
- UAV- The sensors allow us to remain hidden and conduct reconnaissance. When the sensors clear an area then we could move in cautiously, but with a bit more situation awareness than without the sensors. The ability for us to remain hidden from [the] enemy allows us to acquire and destroy them before their forward operators or armor can detect us.
- UGV- UGV had to stay on the road (reference item a). UGV couldn't put be placed in the wood line *(reference item b)*. UGV doesn't have live feed *(reference item c)*. Depends on what UGV is made out of, sight needs more protection *(reference item d)*. UGV is an easy target *(reference item e)*. If a direct hit then no more UGV, from the side, pick up what was left *(reference item g)*. UGV is an easy target *(reference item f)*. If there is a direct hit then no more UGV *(reference item g)*. If there is a direct hit then no more UGV *(reference item h)*.
- PL- Need additional Soldiers on the ground to provide local security.
- TC- [We] only used a surrogate manned platform and the focus [of the test] was on the unmanned systems.

Question 6. Context provided by additional simulated forces.

- UAV- Communications to updates with wingman were not up to speed. Did not really have a good feeling of where other unmanned platforms were.
- UAV- The virtual platforms have everything except the weather (breeze, rain, etc.). Other than that, everything you need is in front of you. Planning and executing the missions and viewing each other online while you pass information back and forth is the same in the virtual world as in the real.

Question 7. Effectiveness of unmanned screen to the flank.

- UAV- Could not differentiate between track and wheeled vehicles. Did not ever see dismounts in the scenarios, don't know if they weren't presented or I just didn't detect them.
- UAV- the UAV was flying entirely too high for me to make anything out on the ground. I could only detect moving vehicles and that also was problematic. The enemy was moving while the UAV was flying over [which] makes it extremely difficult to take pictures and mark and map at the same time.
- UGV- Didn't see any dismounts. The Soldier working on the equipment has to have a working knowledge of the vehicle for it to work.
- CSV- Did not work with enemy dismounted Soldiers. I would have thought them to be vital to the exercise/demonstration.
- PL- Detection is fine; it's a matter of recognizing [in order] to identify enemy.

Question 10. Assessment of utility of planning tools.

- UAV- When planning a route, editing the route must be simplified. Items check "don't know" I did not attempt to utilize functions.
- UAV- The MC2 with enough practice is really good. I would prefer the MC2 over the FBCB2 any day.
- UGV- [When] MC2 doesn't crash it (planning tools) work.
- TC- Did not use all functions listed.

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Appendix F. HRI Questionnaire

1. Position (Check one):   Date: (dd:mm:yy) __ __:__ __:__ __

___ Troop Commander
___ Platoon Leader
___ Chief Scout in Vehicle
__ UAV Operations
___ UGV Operations

Using the scale below, please rate how important it is for the following individuals (identified in each section) to perform the listed Operator Control Unit (OCU) tasks (circle one):

Extremely Unimportant	Very Unimportant	Unimportant	Neutral	Important	Very Important	Extremely Important
1	**2**	**3**	**4**	**5**	**6**	**7**

2. Control unit capabilities

TASK	Rating							
a. Control one small UAV at a time.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**NA**
b. Control one small UGV at a time.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**NA**
c. Control more than one small UAV at the same time.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**NA**
d. Control more than one small UGV at the same time	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**NA**
e. Control multiple systems (UAV/UGV) at the same time (multi-task).	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**NA**
f. Monitor one small UAV at a time.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**NA**
g. Monitor one small UGV at a time.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**NA**
h. Monitor more than one small UAV at the same time.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**NA**
i. Monitor more than one small UGV at the same time	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**NA**
j. Monitor multiple systems (UAV/UGV) at the same time (multi-task).	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**NA**

Comments____

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3. Using the scale below, please rate the importance of having the following characteristics on the OCU (circle one):

Extremely Unimportant	Very Unimportant	Unimportant	Neutral	Important	Very Important	Extremely Important
1	**2**	**3**	**4**	**5**	**6**	**7**

Characteristic	Rating							
a. Joystick control	1	2	3	4	5	6	7	NA
b. Voice control/voice recognition	1	2	3	4	5	6	7	NA
c. Touch screen controls	1	2	3	4	5	6	7	NA
d. Designated buttons	1	2	3	4	5	6	7	NA
e. Hand off control of vehicle to another distant operator	1	2	3	4	5	6	7	NA
f. Greater range from OCU to UAV/UGV (10K or more)	1	2	3	4	5	6	7	NA
g. Operator selected audible/visual/vibratory alerts and warnings	1	2	3	4	5	6	7	NA
h. Brightness control	1	2	3	4	5	6	7	NA
i. Volume control	1	2	3	4	5	6	7	NA
j. Antiglare screen	1	2	3	4	5	6	7	NA
k. Keyboard (part of unit; pop up feature)	1	2	3	4	5	6	7	NA
l. Imbedded map library	1	2	3	4	5	6	7	NA
m. Multiple map scales (e.g. 1/50, 000 or 1/25,000)	1	2	3	4	5	6	7	NA
n. Record image/video feature	1	2	3	4	5	6	7	NA
o. Transmit image digitally	1	2	3	4	5	6	7	NA
p. Take a snapshot image	1	2	3	4	5	6	7	NA
q. Payload interchangeability	1	2	3	4	5	6	7	NA

Comments____

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4. Using the scale below, please rate the importance of the following OCU constraints (circle one):

Extremely Unimportant	Very Unimportant	Unimportant	Neutral	Important	Very Important	Extremely Important
1	2	3	4	5	6	7

Constraint	Rating							
a. Visibility of screen in daylight	1	2	3	4	5	6	7	NA
b. Visibility of screen at night	1	2	3	4	5	6	7	NA
c. Location of controls	1	2	3	4	5	6	7	NA
d. Size of text and map graphics	1	2	3	4	5	6	7	NA
e. Quality of video image	1	2	3	4	5	6	7	NA
f. Quality of map overlay	1	2	3	4	5	6	7	NA
g. Detection range of OCU and operator	1	2	3	4	5	6	7	NA

Comments____

5. What do you see as the training implications for OCU NET?

6. What do you see as the workload implications for the OCU?

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7. What do you see as the combat stress implications for the OCU?

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HRI Survey Comments, Networked Sensors

Q2.

- Troop CDR: [It is] more important to monitor feed from multiple platforms than to control.
- UAV: With multiple sensors employed it is difficult to develop the situation rapidly. I can detect and therefore have to send Soldiers to the areas to develop the situation, orient on the objective, etc. The sensors are good at telling me where something is but as far as applying the fundamentals of scouting it is difficult.
- UAV: Controlling and monitoring1 UAV is busy, once you go to 2 it becomes more difficult.

Q3.

- Plt Ldr: Need to explore teleoperation vs. autonomous/semi-autonomous in regard to human-robot interface.
- UAV: Anything that can make operation of system less taxing should be considered.
- UAV: These characteristics make the system attractive and makes my job of detecting and moving the heavy units to effectively engage and destroy the enemy a lot easier.
- UGV: Viewing UGV spot report should include spot report update pull down options on same screen.

Q4.

- UAV: Seeing the screens in different settings is very important, it makes the difference in seeing enemy units, especially when FLIR is being used.
- UGV: Internal communication headset is needed-communication process is slow and there is slight confusion.

Q5. Training Implications

- Troop CDR: For units to identify Soldiers with greater aptitude, perhaps the use of a simulation to do initial training/testing would be helpful; this will ID the best candidates to become the “SMEs”.
- Plt Ldr: Start familiarization w/in IET environment. Reinforce throughout AIT [advanced individual training] and FCS certification and embedded training.
- Vehicle CDR: Training for this will be intensive and long with reinforcement payoff that should be long-term also.
- UAV: For the UAV operator to be proficient at joystick flying so that if he detects something he can joystick back faster instead of computer re-tasking. UAV operator should also know or have knowledge of vehicle ID.
- UAV: To ensure operator can jump in vehicle to operate <u>all</u> systems.
- UAV: At least 2 weeks of constant training to get a real good feel for it.
- UGV: Target recognition.
- UGV: Very important, could be useful to Soldiers.
- UGV: Having equipment working when “*test it out*” [not clear on this from written comment].

Q6. Workload Implications

- Troop CDR: When the OCU is in use, the operator must be in the “middle” of a formation (protected area). His attention will be focused on the OCU tasks and not on his external security.
- Plt Ldr: Automate as many tasks and crew tasks that occur with a vehicle.
- Vehicle CDR: Pretty manageable but this experiment never really got past 30-40% workload potential it seems.
- UAV: Very little workload to begin with in the OCU, No one is overworked in it.
- UAV: As stated before, system is fine with one UAV flying, becomes less user friendly when two UAVs are up and flying.
- UAV: Live- has a moderate workload. Virtual- it is heavy, very difficult.
- UGV: Not bad just need to fine tune.
- UGV: UGV is easy to control. UAV there is a lot more to do.

Q7. Combat Stress Implications

- Troop CDR: No different than anyone else in combat.
- Plt Ldr: With Soldiers more attuned to computer screens, who is providing local security?
- Vehicle CDR: Too much info for a Soldier at any rank to handle efficiently. Important info will be buried in unimportant reports, photos, links, etc.
- UAV: Very little if any at all.
- UAV: It could be stressful on the eyes-also, hands and wrist could be affected. In my opinion it could stress Soldiers out if system is not updated to handle more than one UAV better.
- UAV: I feel that there is no stress in the virtual world only frustration.
- UGV: If system doesn’t up-link or system crashes.
- UGV: Minimal. Failure to gather information which results in combat loss.

Appendix G. Networked Sensors Questionnaire

UAV MC2-UMS Questionnaire (questionnaire addresses EEA 3.6)

_______________Date ______________ PIN _______________Sub-test

Rate how the interface design helps you perform the following tasks on the scale below:

Task	**Very Poor**	**Poor**	**Borderline**	**Good**	**Very Good**	**NA**
a. Select new course of action						
b. Select appropriate UAV						
c. Select map						
d. Zoom in and out on map						
e. Draw area of coverage						
f. Plan UAV route(s)						
g. Display sensor fan						
h. Launch the UAV(s)						
i. Monitoring flight of UAV(s)						
j. Altering route of UAV(s) in flight						
k. Monitoring what the UAV(s) is (are) seeing						
l. Quality of sensor imagery						
m. Ability to identify targets						
n. Sending reports on what the UAV(s) see(s)						

Comments: Provide comments on good and bad aspects of interface design, and recommended changes to the interface

UGV MC2-OCU-UMS Questionnaire

_______________Date _______________ PIN _______________Sub-test

Rate how the interface design helps you perform the following tasks on the scale below:

Task	**Very Poor**	**Poor**	**Borderline**	**Good**	**Very Good**	**NA**
a. Select new course of action						
b. Select appropriate UGV						
c. Select map						
d. Zoom in and out on map						
e. Draw area of coverage						
f. Plan UGV route						
g. Display sensor fan						
h. Monitoring path of UGV						
i. Altering route of UGV (e.g., for surveillance of another area)						
j. Monitoring what the UGV is seeing						
k. Automatic target detection-aided target recognition						
l. Ability to identify target						
m. Ability to get accurate far target locations						
n. Controlling what the UGV is seeing						
o. Sending reports on what the UGV sees						

Comments: Provide comments on good and bad aspects of interface design, and recommended changes to the interface

UGS MC2-UMS Questionnaire

_______________Date ______________ PIN _______________Sub-test

Rate how the interface design helps you perform the following tasks on the scale below:

Task	**Very Poor**	**Poor**	**Borderline**	**Good**	**Very Good**	**NA**
a. Select new course of action						
b. Select TDA						
c. Select map						
d. Zoom in and out on map						
e. Draw area of coverage						
f. Select observation point location						
g. Emplace UGS						
h. Select imager location						
i. Manually adjust coverage						
j. Display sensor fans						
k. Monitor coverage of sensors						
l. Quality of sensor imagery						
m. Ability to generate an image of the target						
n. Ability to identify the target from the imagery						
o. Send SITREP of sensor snapshot						

Comments: Provide comments on good and bad aspects of interface design, and recommended changes to the interface

UAV UMSC Questionnaire (questionnaire addresses EEA 3.6)

______________Date ______________ PIN ______________Sub-test

Rate how the interface design helps you perform the following tasks on the scale below:

Task	**Very Poor**	**Poor**	**Borderline**	**Good**	**Very Good**	**NA**
a. Plan UAV route(s)						
b. Launch the UAV(s)						
c. Monitoring flight of UAV(s)						
d. Altering route of UAV(s) in flight						
e. Monitoring what the UAV(s) is (are) seeing						
f. Sending reports on what the UAV(s) see(s)						

Comments: Provide comments on good and bad aspects of interface design, and recommended changes to the interface

UGV UMSC Questionnaire

_______________Date _______________ PIN _______________Sub-test

Rate how the interface design helps you perform the following tasks on the scale below:

Task	**Very Poor**	**Poor**	**Borderline**	**Good**	**Very Good**	**NA**
a. Plan UGV route						
b. Monitoring path of UGV						
c. Altering route of UGV (e.g., for surveillance of another area)						
d. Monitoring what the UGV is seeing						
e. Controlling what the UGV is seeing						
f. Sending reports on what the UGV sees						

Comments: Provide comments on good and bad aspects of interface design, and recommended changes to the interface

UGS UMSC Questionnaire

_______________Date ______________ PIN _______________Sub-test

Rate how the interface design helps you perform the following tasks on the scale below:

Task	**Very Poor**	**Poor**	**Borderline**	**Good**	**Very Good**	**NA**
a. Select observation point location						
b. Emplace UGS						
c. Select imager location						
d. Manually adjust coverage						
e. Monitor coverage of sensors						
f. Send SITREP of sensor snapshot						

Comments: Provide comments on good and bad aspects of interface design, and recommended changes to the interface

Interface Survey Comments

UAV MCS Survey

Participant 1: Design – not ambidextrous (needs a left and right handle)

Participant 2: Launching the UAV has to be easier
Monitoring 2 or more UAVs is a little taxing
Route of UAV in re-tasking takes too long to re-adjust
Need more control of camera
Imagery is very poor; can only detect target
Cannot ID any targets

Participant 3: I think there should be some type of a catapult to launch the UAV only because I have a physical disadvantage in which I couldn’t launch a UAV

Instead of altering the route or re-tasking as it is referred to, if I see something during flight I’d rather have a remote controller so that I could manipulate the aircraft to do what I need

UAV UMCS Survey

Participant 1: The picture quality (when spot report goes to RSV commander) the picture with description should instantly come up when it’s enemy

Participant 2: Launching UAV takes too much time in pre-flight test and if launch is not successful, re-testing and re-launch attempt

Re-tasking took 3-5 minutes to go from my workstation to UAV engineer, by that time object that I want to see will probably be gone

You get one shot at what UAV is seeing and if you take a picture, quality is so poor that it cannot be classified or ID’d

Participant 3: You can’t launch the system, just test for launch

UGV MC2 Survey

Participant 1: There was a problem re-tasking the UGV on several occasions

Participant 2: No comments

Participant 3:
a. Easy with COA if UGV cab receive the command
b. Easy
c. Easy
d. Easy
e. Easy
f. Can’t plan in depth route recon
g. Easy
h. No live feed – can’t see on the move
i. If UGV can receive the command
j. No live feed
k. Didn’t use
l. Can see something
m. Can see something but can’t truly ID
n. Controller needs to control the sight and live feed
o. Easy

UGV UMCS Survey

Participant 1: No comments

Participant 2: No comments

Participant 3: a. Program does not allow you to plan in-depth route recon

b. Current system doesn't allow monitoring the path of the UGV – the movement's blind

c. Re-tasking route easy – sending signal from RSV to UGV was poor

d. Seeing what the UGV is seeing isn't live feed so you have to wait for picture

e. Controlling with the interface easy but re-task each time need ti be controlled by the controller

f. Easy sending reports

UGS MC2 Survey

Participant 1: Improve software integration

Understand that different software may not facilitate seamless information and functionality flow, but that is the battle command software that we will be working with in the future

Participant 2: Sensors provided highly redundant SITREPs and snapshots. Once showed five unknown targets, but only one vehicle was there. Each sensor generated a spot report that was in my estimation too premature. This could lead to a crippling instance of data overload on the user-scout.

Participant 3: SUAV image is hard to use to ID the target – when you re-task the SUAV it climbs to a higher altitude.

CETS imagery is good and can be used to classify targets

UGS UMCS Survey

Participant 1: Not enough hands-on work due to software compatibility

Participant 2: No comments

Participant 3: No comments

Appendix H. AAR Interviews

AAR Questions for Networked Sensor (all questions addresses EEA 3.6)

________________Date   __________________Sub-test

UAV-MC2-UMS controller
- How well did the interface facilitate your route planning? What were the major problems? What features were especially good?

- How well did the interface facilitate launching the UAV? What were the major problems? What features were especially good?

- How well did the interface facilitate monitoring flight of the UAV? What were the major problems? What features were especially good?

- How well did the interface facilitate monitoring flight of multiple UAVs? What were the major problems? What features were especially good?

- How well did the interface facilitate altering the route of a UAV in flight? What were the major problems? What features were especially good?

- How well did the interface facilitate monitoring the input of the sensor? What were the major problems? What features were especially good?

- How well did the interface facilitate monitoring the input of multiple sensors? What were the major problems? What features were especially good?

- How good was the sensor imagery? Were you able to identify targets?

- How well did the interface facilitate controlling the view of the sensor? What were the major problems? What features were especially good?

- How well did the interface facilitate sending reports based on sensor information to higher? What were the major problems? What features were especially good?

________________Date ____________________Sub-test

UGV-MC2-OCU-UMS controller

- How well did the interface facilitate your route planning? What were the major problems? What features were especially good?

- How well did the interface facilitate monitoring the progress of the UGV? What were the major problems? What features were especially good?

- How many times did you have to intervene to control movement of the UGV (e.g., stuck at obstacle in path)? What features were especially good?

- How well did the interface facilitate controlling specific movements of the UGV (e.g., guiding it around an obstacle in its path)? What were the major problems? What features were especially good?

- How well did the interface facilitate major alterations in the route of a UGV (e.g., changing the general route because of a more important target)? What were the major problems? What features were especially good?

- How well did the interface facilitate monitoring the input of the sensor? What were the major problems? What features were especially good?

- How well did the automatic target detection – aided target recognition work? What were the major problems? What features were especially good?

- Were you able to identify targets and get accurate far target locations?

- How well did the interface facilitate controlling the view of the sensor? What were the major problems? What features were especially good?

- How well did the interface facilitate sending reports based on sensor information to higher? What were the major problems? What features were especially good?

________________Date   __________________Sub-test

UGS-MC2-UMS controller

- How well did the interface facilitate your planning of sensor coverage? What were the major problems? What planning tools were especially good?

- How did you select your locations for the UGS?

- How well did the interface facilitate your emplacing sensors? What were the major problems? What features were especially good?

- How well did the interface facilitate monitoring the input of multiple sensors? What were the major problems? What features were especially good?

- How good was the sensor imagery? Were you able to generate an image of the target? Were you able to identify the target from the imagery?

- How well did the interface facilitate sending reports based on sensor information to higher? What were the major problems? What features were especially good?

Participant Comments on Interface AARs

UAV AAR
19 September 2005

1. The planning tool worked but once you get the screen to where you're comfortable you wouldn't know the zoom percentage. The zoom needs to be fine tuned. The route planning was pretty easy, not difficult to do. Fine tuning and/or adjusting a route is difficult. You may have to delete a route (and start all over) in order to fine tune it the way you need it.
2. There should be a self test to it where 2 people wouldn't need to be put out for pre-flight of the UAV. So, need a self pre-flight checklist. In an accident (if the UAV goes down) the operator has to bring it back, put it back together, perform a pre-flight check and then launch it again. Need more of a helicopter than a fixed wing UAV for getting target-able data. Target-able data were not provided in the UAV during this exercise- the operators said that they needed a helicopter type of UAV for that. You could use the images to bring other assets on board but can't be used alone as a targeting tool.
3. You can look at the screen and see the UAV flying- in that portion it did well. You can monitor its route and progress.
4. No problems with flying multiple UAVs.
5. Re-tasking is easy to do on the computer but it was 3-5 minutes to take the screen to update. When it did update at times it could have been too late. Adjusting waypoints was a nightmare; the screen wouldn't refresh quickly at all. It was easier to delete a flight plan and re-do it. Re-tasking could be especially bad when flying multiple UAVs (below).
6. There is no way to see behind where the UAV has flown- the operator has to re-task and then loop around. There is no north seeking icon; without a north seeking icon it's hard to tell what direction the target is facing (in relation to the UAV) as you have to do perform mental calculations.
7. Operators have to keep their eyes on all three screens (for three UAVs) and then once they get detections on all three screens it gets busy. Need to distinguish the priority of targets as workload is already very high, especially with the burden of having to perform re-tasking. Network AiTR with a playback feature would be good.
8. skip
9. Couldn't adjust the camera, had to maneuver the plane. SIDE NOTE by Cpt. David: One sensor one Soldier, especially with teleoperated vehicles.
10. There was some time between sending reports and having them be received. It's easier to look at the other crewmembers screens rather than go through the formal reporting process. The feature for the VC to look at another's screen should be easier to use. As targets are ID'd, spot reports will be generated and Soldiers will soon be buried in spot reports. Operators expressed concerns about the workload associated with collecting the sensor information and then managing it. Filter needs to happen within a TOC; Soldiers were asking for sensor fusion.

Final Comments

1. When you have to type in a spot report, need a drop down option for target information. Or voice recognition.
2. Would like “tank” icons.
3. When you plot an “unknown” target, there needs to be a way to refresh the MC2 so that the icon doesn’t fade away. If there is a way, the Soldier didn’t’ know what it was. It should stay there until notified as a target that can be listed as “gone”.

UGV AAR

19 September 2005

1. Accomplished planning OK. Tried to use the FAS to get a scan area during planning but you can’t do that. It seemed like it would be a good capability but the software wouldn’t allow it. Instead you recon, then do a FRAGO (re-task) for the scan area.
2. It tracked, and received positive feedback from the MC2 and got good pictures. Seemed like it would provide a streaming video but it does not.
3. Didn’t have any problems getting around barriers, stuck with the roads so no opportunity to really test out this question (having to intervene to control movement of UGV). The chase vehicle operator would have maneuvered around obstacles and the UGV operator may not have even known about it- especially if the obstacle was small.
4. skip
5. A big problem in the software was that the operator couldn’t re-task. Several causes for this inability to re-task were encountered; on one occasion the operator couldn’t get a hot mouse, another time the vehicle wasn’t logged on properly. Many times and in many ways re-tasking was a problem. One time it did re-task but then shortly after it wouldn’t function correctly.
6. There were 2 types of pictures, panoramic and chip. With panoramic pictures the operator could ID a vehicle. It was hard to ID vehicles with the chip as it was small.
7. skip
8. Operator couldn’t ID far targets.
9. There was no problems encountered with positioning the UGV camera because the chase vehicle put UGV in an optimal position; there was no need to reposition the sensor.
10. skip

Final comments:

1. Re-tasking was a continual problem.

UGS AAR
19 September 2005

1. Operators could go in and adjust the sensor placement manually. Didn't get as far as emplacing the UGS but did plan for it. The planning tool was good.
2. Once you draw NAI the program will determine the best location for the sensor- called auto emplacement. Soldiers, however, built their own NAIs. Soldiers wanted to see if self-emplacement of the UGS would affect connectivity to the gateway. There's an option to see your connectivity in the program but the operators didn't get far enough along in their experience to do that.
3. skip
4. 5 icons and spot reports came up for a tractor that came by the UGS field. The operator knew it was a tractor but the UGS interface showed 5 icons and 5 spot reports. While there was actually only one target (the tractor) It would have been alarming for the operators if it were dark outside. The reliability isn't good enough to rely on it. In a second, the operator was bombarded by 10 plus reports. Icons showed up on the screen but operators weren't sure if they were accurate.
5. No imagery.
6. No spot reports sent.

UGS Training AAR – Thursday 15 Sep

- UGS run observations: Re-naming the NAI was difficult, had to have help. The collaboration software is a major problem. The person producing the graphics has to be in collaboration, and the person to receive them has to be out of collaboration until the graphics are finished. Graphics were produced and lost numerous times trying to establish collaboration. The UGS operator said his "fingers were too fat" for the touch screen – need a stylus.

- UAV run observations: Editing a route was difficult for UAV. It was virtually impossible to adjust the diameter of a hover route. The operator had to delete and set a new radius. The UAV operator stated that tracking the video feeds from two UAVs simultaneously was difficult.

AAR observations: The mission was to plan and monitor one, and later two, UGS fields. There were no problems planning the UGS field. The operator could see the track on the screen and also use a "track" button to track moving vehicles for up to 300m. The operator used the information on time, location, and sensor the information came from provided by the screen display. The operator preferred visual cues, such as the located target on the screen. When asked if they would like the target and the sensor that located it to flash a few seconds after detection, rather than a text read out, they indicated acquiescence. The UGS operator (platoon leader) also wondered if a platoon leader in an actual mission would have time to monitor the UGS.

A few suggestions for improvement were made. For instance, how can you tell the number of vehicles being tracked if there are multiple detections – is it different sensors locating the same vehicle or are there different vehicles? Some level of data fusion or correlation is required by the software; this cannot be left completely up to the operator. Also, just because three UGS fields are available, it may not be advisable to always use all three. A long discussion entailed about who controls placement of UGS – the battalion BIC (as in UAMBL experiments) or the vehicle or platoon, as in this

UGV Training AAR – Wednesday 14 Sep

O Mission included
- Route planning
- Re-tasking (changing route)
- Reconnaissance of NAI

With the training received, route planning was easy (select terrain, select sensor, plan route, mark waypoints with “hot mouse”). However, the software to re-task (in this case adjust the sensor to scan for the target) did not work. The software was easy to use, but just did not function. Participants had to plan a new route to spread or narrow the view at waypoints.

There are two sensor views; panoramic and chip. In the panoramic view, participants could detect hotspots. This could be due to either placement of the UGV or sensor performance. Participants said that chip images are small and hard to see. This could reflect a lack of training, since chip images can be enlarged. In the chip view, they could perhaps classify targets.

Workload in this limited scenario was reasonable. However all that participants did was observe the UGV and the NAI. No spot reports were sent.

Participants were curious about how multiple targets in one sensor feed would be handled (i.e., fusion of information so one can tell how targets are located in relation to each other).

Live sensor feeds may be needed to adjust sensor into a position to cover the NAI. Also a mast up to 15 feet may be needed. Also, perhaps the UAV could be used to emplace the UGV, since placing the UGV with just the map overlay was not sufficient. Also, the SOP was that the UGV be limited to range roads, so participants could not tell how easy or difficult it would be to place the UGV to oversee the NAI.

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Appendix I. Anthropometric Measures

SOLDIER ANTHROPOMETRIC QUESTIONNAIRE

1) Date: ___ ___ / ___ ___ ___ / ___ ___
(DD/MMM/YY

2) ____ UAV Operations   _____ UGV Operations   _____ UGS Operations

3) Gender: ☐ Male ☐ Female

4) Do you require mandatory wear of corrective lenses? ☐ No ☐ Yes

5) If "YES " to Question # 6, do you wear glasses or contact lenses?

☐ Glasses ☐ Contact lenses ☐ Both

6) Do you require vision correction for near sightedness? ☐ No ☐ Yes

7) Do you require vision correction for far sightedness? ☐ No ☐ Yes

8) Do you require vision correction for reading? ☐ No ☐ Yes

9) What is your preferred writing hand?

☐ Left ☐ Right ☐ Both

ANTHROPOMETRIC MEASUREMENTS

10) PT Uniform Weight: ____ ____ ____
(lb)

11) PT Uniform Height: ____ ____ ____
(cm)

TYPE MEASUREMENT	DIMENSION (cm)
12) Sitting height (93)	
13) Sitting eye height (49)	
14) Thigh clearance (104)	
15) Knee height, sitting (73)	
16) Popliteal height (86)	
17) Buttock-knee length (26)	
18) Buttock-popliteal length (27)	
19) Bideltoid breadth (12)	
20) Forearm-forearm breadth (53)	
21) Hip breadth, sitting (66)	
22) Abdominal extension depth, sitting (1)	
23) Functional leg length (55)	
24) Elbow to fingertip/grip length (D17)	
25) Thumb-tip reach (106)	

Appendix J. Training Survey

Last Name: _______________ Test Position: ________________ Date: __________

Training on MC2

1. Did the classroom training **provide the essential information** needed to conduct your test duties, or did you **require additional sidebar help** when you started conducting your test duties?

    ❍Provided the essential information ❍Required additional sidebar help

    If you required additional help, please briefly explain:

2. Did the classroom training **give you confidence** in your ability to use MC2 to support your test duties?

    ❍Yes ❍No

    If you selected "No", please briefly explain:

3. Did the classroom training teach you MC2 **features and capabilities**?

    ❍Yes ❍No

    If you selected "No", please briefly explain:

4. Did the classroom training teach you **HOW to use those features and capabilities** to conduct your test duties?

    ❍Yes ❍No

    If you selected "No", please briefly explain:

5. What **suggestions** do you have to improve the MC2 training you received?

<u>Training on UMS</u>

1. Did you receive adequate training on the UMS **features and capabilities**?

   ❍Yes ❍No

   If you selected "No", please briefly explain:

2. Did your UMS training teach you **HOW to use those features and capabilities** to conduct your test duties?

   ❍Yes ❍No

   If you selected "No", please briefly explain:

3. Once your training on UMS was completed did you **require additional sidebar help** when you started conducting your test duties?

   ❍Yes ❍No

   If you selected "Yes", please briefly explain:

4. Did the training **give you confidence** in your ability to use the UMS to support your test duties?

   ❍Yes ❍No

   If you selected "No", please briefly explain:

5. What **suggestions** do you have to improve the UMS training you received?

6. Applied Training (using MC2 and UMS to complete missions)

7. Did you receive adequate training on using MC2 and UMS together to complete your test duties?
   ❍Yes ❍No

   If you selected “No”, please briefly explain:

8. How was training conducted to ensure that you could use MC2 and UMS to conduct your test duties? Please describe here:

9. What suggestions do you have to improve the applied/field/hands on training? Please list here:

Overall

1. Now that you have begun your test duties, what aspects of MC2 and/or UMS training have helped you most? Please list here:

2. Now that you have begun your test duties, what aspects of MC2 and/or UMS training were missing or inadequate for you to complete your test duties? Please list here:

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Appendix K. Training Comments

MC2 Training Comments:

- Need to teach the concept of graphic overlays and how to share them. We did not go in depth on execution functions.
- More training on the creation, collaboration and passing of graphical control measures.
- Some of the sequences changed once Soldiers were in the RSV
- Not all features and capabilities were taught in the classroom because many of those things are easier to understand once you have the hands-on experience.
- Touch screen monitors for the classroom to mimic the real screens would be good.
- Training on tracking, identifying, classifying and detecting targets in the classroom would be good [not necessarily related to MC2 but still good info].
- There shouldn't be days between the classroom and the hands on training; recommend same day or next day hands on after classroom training.
- MC2 training on features and capabilities was only at the basic level- not enough to make you proficient on MC2.
- More training is the only way to achieve and maintain proficiency.
- During testing (planning or execution), I often forgot a step and/or the system would crash.
- Would take a lot of time to become proficient and confident.
- The training gave me the basic features to perform my role in the test but more training is required to be really proficient at using it.
- UGS training required some additional training because the planning tool used during the test was not exactly the same as that used during training.

UMS Training Comments:

A. UAV operators:

- Additional sidebar help was needed only to ensure that I was taking the right steps to do certain procedures.
- Need more hands on with the equipment.
- Again, some things you just can't replicate in the classroom, they come into better understanding once you are in the vehicle.
- Had to wait until I was on the UAV to actually use the UMS
- There was hardly any UMS training in the classroom because you cannot replicate a UAV in flight in the classroom. If you could, then the training would be better.
- Additional help needed with re-tasking to reposition the UAV.
- Confidence will only come with practice. We need to be able to use every aspect of MC2 over and over again. It all depends on the individual and their capacity to learn and feel comfortable with MC2.

B. UGV operators:

- Need to utilize re-task during training.

- Need more familiarization.
- Need more practice.

C. Vehicle Commander:
- Need more hands on work
- Would like to know technical specifications of the software
- Not enough hands on training in live or virtual
- Learned how to use the UMS by actually doing it
- Need to integrate the concepts of tele-operation (i.e., universal controller) into the UMS

D. Troop Commander:
- Sidebar help was needed if a task was forgotten or degraded after classroom instruction.

Appendix L. Experimental Scenarios

Integrated Exercise

1. Background:

a. The system sub-tests provide the user a sound understanding of the capabilities of the three systems: SUAV, UGS, UGV and the opportunity to demonstrate performance representative of the exit criteria.

b. The higher level objective of the ATD has been to produce a system of systems that includes the sensors and the command and control tools to facilitate their use. This system of should:

1). Increase the tempo of reconnaissance operations

2). Increase the area that can be covered by reconnaissance units

3). Reduce the vulnerability of manned systems by using unmanned assets to make contact with the minimum possible force – make sensor contact before manned assets come within range of enemy systems.

c. To provide the opportunity to employ and observe the performance of the system of systems an Integrated Exercise is included in the ATD Exit Demo. The Integrated Exercise design is limited by key resources: terrain available for maneuver, experimental assets, support assets to provide operators and targets/threat forces, and time. Within those constraints scenarios the design will provide the opportunity to gain insights into those top level issues and the specific MOP listed below.

2. Measures of Performance

- How well does the suite of systems enable reconnaissance missions: route, area, zone
- How well does the suite of systems enable the crew to conduct screen missions?
- How well does the suite expand the area that can be covered by reconnaissance organizations beyond just the manned systems?
- How well does the suite increase the tempo of reconnaissance operations
- How well does the suite enable the scout to make sensor contact before direct contact
- How well do the sensors produce target-able information: timeliness, target location accuracy, ability to detect, classify, recognize and identify?
- What are the implications on the RSV crew of employing the unmanned sensors (UMS), work load, training, task complexity?
- How well do the command and control and planning tools work to enable the scout to plan, employ and exploit the sensors?
- How well do the sensors enable the FCS concept of networked lethality. What capabilities must be added or expanded?

3. Use of simulation.

The exercise will be designed to use virtual and constructive simulation in conjunction with the experimental systems. The integration of live and virtual experimentation has been an objective of the UAMBL Experimentation and Analysis Directorate and the NSFF demo provides the opportunity to gain experience with this expanded test environment. The use of simulation allows the ATD to provide a broad tactical context to the scenario, add additional assets to the operation. The concurrent use of simulated and live assets will provide the user the opportunity to compare what is being portrayed in current simulations with the systems that are actually emerging from R&D.

4. Overview:

a. The tactical organization in which the experimental and simulated assets will be placed is based on organizations described in the FCS O&O. It is centered on the Recon Platoon of the Recon Troop of the Combined Arms Battalion.

1). The RSV will be the Recon Platoon Leader's RSV

2). The other two RSVs in the platoon will be represented by crewed, man-in-the loop ACRTs located in the Mounted Warfare Test Bed.

3) The Troop Commander of the Recon Troop will operate either from the RSTA vehicle at the testing site, or the workstation at the MWTB. Probably the latter, so he can orchestrate the entire operation.

4) The other two platoons of the troop will be replicated in OTBSAF in the MWTB, and maneuvered per the direction of the Troop Commander.

b. This representation balanced limited assets with the capability of providing tactical context, and cues from the majority of elements with which the platoon leader would normally interact. Additionally it provides a good test of the live/simulation interface. If these levels can be effectively operated, a much broader "virtual war" could be used in other experimentation.

c. The live threat vehicles that will face the RSV and its unmanned systems will be systems on the ground played by the limited number of actual vehicles assigned to the experiment. They will respond to the white cell in the MWTB. The other threat systems will be replicated in OTSB and visible to the ACRTs on the virtual battlefield, and when reported show as ICONs to the RSV via MC2.

d. The scenario will be constructed to place the experimental assets in Training Areas 9 and 10 on the western edge of the Fort Knox reservation. Simulated elements will operate in the terrain adjacent to those maneuver areas.

The situation portrays that the UA has advanced Northeast toward Brandenburg, Fort Knox and the Ohio River. The Recon Troop has moved ahead of the CAB and is closing in on Highway 60 from the south. Intelligence assets has reported that the enemy is trying to use Highway 31 W to move its surviving forces north to Louisville, using the bridge over the Salt River in West Point and the range road bridge over the Salt River in GS 9405. The enemy has placed a light screen of a variety of vehicles east of a line from Vine Grove (9085) to Basham's Corner (98494) to the Ohio River (8201) apparently to provide early warning to its forces that will move north along 31W.

The Troop Commander issues a FRAG O to his forces summarizing that information and providing the following mission task and purpose for his platoons:

Troop A continues its attack to seize crossing sites over the Ohio River vic Brandenburg to support advance of the CAB to objectives west of Louisville.

1st Platoon conducts zone reconnaissance east to 31W between Ft Knox/Vine Grove Road on the south, Highway 60 center, to Ohio River (8201) on the north. Locate and destroy by indirect fires enemy screening elements. Establish screen along Ft Knox/Vine Grove Road to provide early warning to CAB of enemy forces that may maneuver west of 31 W attempting to use Brandenburg bridge. On order establish OP's overwatching 31W and bridges over Salt River to coordinate Joint Fires on fleeing enemy along 31W.

2d Platoon conducts zone reconnaissance along and east of Highway 144/448 to high ground south of Ohio River….

3d Platoon conducts zone reconnaissance west of Highway 144/448 to secure entrances of Brandenburg to enable passing CAB attack across the Ohio River.

This scenario allows the experimental assets to be used in TA 9 with ACRT assets used north of highway 60. Or for the experimental assets to be used in TA 10 with ACRT assets in TA 9 and north of highway 1638. It also provides sufficient separation so that intervisibility both between the elements of the platoon and between platoons is not likely.

e. The suggested sequence would be for the exercise director to script the employment of the unmanned experimental assets against a target set in TA -9. By influencing the routes, OP's and NAIs contact between the sensors and the threat forces can be insured. This would be repeated in TA-10 with a similar scenario. Then the scripting restrictions would be relaxed and the platoon leader would be free to employ the assets as needed to accomplish the mission in TA -9 and another run in TA-10. AND in these the OPFOR would be given the mission to attempt to avoid and bypass these assets, gaining control of Basham's corner with minimal restrictions.

f. The ACRT crews would conduct their missions in the virtual battlespace, engaging virtually simulated Threat Forces, reporting their activity to the platoon leader and receiving updates and guidance from him. The Troop Commander would report Troop and CAB activities and while monitoring the activity in 1st Platoon zone via MC2 and interaction with the platoon leader. (Additionally he would provide guidance to both Blue and Red workstation operators to maneuver virtual Threat units and adjacent Blue units.)

5. Location of Assets: The RSTA vehicle and the RSV will start at Basham's corner. The RSV will maneuver as necessary to control the unmanned assets and accomplish the mission.

6. Communications: TBP

7. Description: The platoon leader will use MC2 to plan the use of the unmanned assets. UGS will be manually emplaced according to his plan. Threat systems will be positioned with scripted behaviors. This will include vehicle in hide position along UGV route. The platoon leader begins reconnaissance of his zone with the end state of establishing a screen to the south and an OP on Snow Mountain to the east.

8. Data Collected:

Location of RSV throughout the trial

Location of threat vehicles throughout trial

Routes chosen for UGV and location of OP and movement technique employed
Assessment of imagery and information provided by UGV along route
Final selected OP for UGV
Targets detected and IDed by UGV including time
FTL of targets
Timeline to generate call for effects based on UGV imagery
UAV planned route and search patterns
Targets detected by UAV, FTL and time
Location of UGS fields, gateways and patterns
Location and time of UGS field detections and tracks
Questionnaires:

- Assessment of coverage of zone
- Assessment of speed of reconnaissance
- Assessment of survivability provided to RSV by unmanned sensors
- Assessment of context provided by additional simulated forces
- Assessment of effectiveness of unmanned screen to flank

Assessment of ability of sensors to provide targetable data (ID, location, timeliness)
Assessment of workload of RSV crew in employing sensors, maneuvering the RSV and commanding the platoon
Assessment of utility of planning tools in developing a system of systems employment plan for the sensors

Appendix M. Data Tables

Table M-1. Area of coverage for networked sensors versus current systems

Survey Item	Smaller	Same	Larger
Width of zone that can be effectively covered (9)	11	22	67
Depth of zone that can be effectively covered (9)	11	22	67
Overall area of zone that may be effectively covered (8)	0	50	50
Overall area that can be covered in terrain involved in test (8)	12	25	63
Overall area that you think can be covered in open terrain (9)	0	0	100
Overall area that you think can be covered in urban terrain (8)	25	12	63
Code: - numbers in columns indicate percent of provided responses. - green indicates majority of respondents answering favorably. - yellow indicates respondents had no strong preference. - red shows a majority answered unfavorably. - no color indicates a lack of a majority in any category. - numbers in parentheses indicate sample size.			

Table M-2. Speed of reconnaissance for networked sensors versus current systems

Survey Item	Slower	Same	Faster
Speed of developing a plan, including reconnaissance routes for UAVs and UGV and placement of UGS (9)	11	22	67
Speed of deploying reconnaissance assets (time from when plan is developed until UAVs and UGV begin their routes and until UGS are deployed) (9)	33	11	56
Speed of completing route reconnaissance (all tactically significant aspects of the route are identified) (7)	28	57	14
Speed of completing area reconnaissance (all tactically significant aspects of the area are identified) (9)	22	44	33
Speed of completing zone reconnaissance (all tactically significant aspects of the zone are identified) (9)	22	33	44
Code: - numbers in columns indicate percent of provided responses. - green indicates majority of respondents answering favorably. - yellow indicates respondents had no strong preference. - red shows a majority answered unfavorably. - no color indicates a lack of a majority in any category. - numbers in parentheses indicate sample size.			

Table M-3. Survivability for networked sensors versus current systems

Survey Item	Less	Same	More
Conducting route reconnaissance (7)	43	29	28
Conducting area reconnaissance (8)	38	38	24
Conducting zone reconnaissance (8)	38	38	24
Threat with small arms (8)	50	12	38
Threat with RPG (9)	67	0	33
Threat with IED (8)	63	12	25
Threat with armored vehicle (9)	56	22	22
Threat with mortar (9)	56	33	11
Threat with artillery (9)	45	44	11
Code: - numbers in columns indicate percent of provided responses. - green indicates majority of respondents answering favorably. - yellow indicates respondents had no strong preference. - red shows a majority answered unfavorably. - no color indicates a lack of a majority in any category. - numbers in parentheses indicate sample size.			

Table M-4. Ability to detect targets

Survey Item	***Percent Good* or *Very Good* responses**
Ability to detect dismounts (7)	43
Ability to detect w heeled vehicles (9)	67
Ability to detect tracked vehicles (9)	67
Ability to detect squad sized entities (8)	50
Ability to detect platoon size entities (generalize based on your experience in this demonstration) (9)	56
Ability to detect company sized entities (generalize based on your experience in this demonstration)(9)	67
Code: - numbers in columns indicate percent of provided responses. - green indicates majority of respondents answering favorably. - yellow indicates respondents had no strong preference. - red shows a majority answered unfavorably. - no color indicates a lack of a majority in any category. - numbers in parentheses indicate sample size.	

Table M-5. Ability to provide target-able data

Survey Item	***% Good* or *Very Good* responses**	**Survey Item**	***% Good* or *Very Good* responses**
Ability to detect dismounted entities (6)	50	Ability to detect tracked entities (9)	55
Ability to classify dismounted entities (6)	33	Ability to classify tracked entities (8)	37
Ability to recognize dismounted entities (6)	33	Ability to recognize tracked entities (9)	33
Ability to identify dismounted entities (6)	33	Ability to identify tracked entities (9)	44
Ability to provide accurate target location on dismounted entities (6)	50	Ability to provide accurate target location on tracked entities (9)	44
Ability to provide timely information on dismounted entities (6)	67	Ability to provide timely information on tracked entities (9)	67
Ability to detect wheeled entities (9)	67	Ability to detect potential IEDs (4)	0
Ability to classify wheeled entities (8)	50	Ability to classify potential IEDs (4)	0
Ability to recognize wheeled entities (9)	44	Ability to recognize potential IEDs (4)	0
Ability to identify wheeled entities (9)	22	Ability to identify potential IEDs (4)	0
Ability to provide accurate target location on wheeled entities (9)	22	Ability to provide accurate target location on potential IEDs (4)	25
Ability to provide timely information on wheeled entities (9)	55	Ability to provide timely information on potential IEDs (4)	50

Code:
- numbers in columns indicate percent of provided responses.
- green indicates majority of respondents answering favorably.
- yellow indicates respondents had no strong preference.
- red shows a majority answered unfavorably.
- no color indicates a lack of a majority in any category.
- numbers in parentheses indicate sample size.

Table M-6. Maneuver command and control (MC2) survey data

Operator Task	**UAV**	**UGV**	**UGS**
Select new course of action	67	100	100
Select appropriate sensor	100	100	100
Select map	100	100	100
Zoom in and out on map	100	100	100
Draw area of coverage	67	100	100
Plan sensor route(s)-location	100	67	67
Display sensor fan	100	100	100
Select OP location (UGS only)	NA	NA	67
Select imager location (UGS only)	NA	NA	100
Manually adjust coverage (UGS only)	NA	NA	67
Monitoring path (coverage for UGS) of sensor	100	67	67
Altering route of sensor (UAV and UGV only)	33	0	NA
Sending spot reports on MC2	67	67	67
Code: - numbers in columns indicate percent of provided responses. - green indicates majority of respondents answering favorably. - yellow indicates respondents had no strong preference. - red shows a majority answered unfavorably. - no color indicates a lack of a majority in any category.			

Table M-7. MC2 mission planning tools

Survey Item	***Percent Good* or *Very Good* responses**
Select new course of action (7)	100
Select sensor (8)	87
Select map (9)	100
Zoom in and out on map (9)	100
Draw area of coverage (9)	100
Plan UAV route(s) (9)	100
Line of sight tool (8)	100
Distance tool (7)	86
Friendly direct fire fans (5)	80
Enemy direct fire fans (5)	80
Enemy ADA circles (5)	100
Inter-visibility plot (7)	86
Elevation plot (6)	83
Mobility plot (6)	83
Sensor coverage plot (7)	100
Plan view (6)	100
Blue plan-current situation view (7)	100
All plan-current situation view (5)	100
Code: - numbers in columns indicate percent of provided responses. - green indicates majority of respondents answering favorably. - yellow indicates respondents had no strong preference. - red shows a majority answered unfavorably. - no color indicates a lack of a majority in any category. - numbers in parentheses indicate sample size.	

Table M-8. UMCS survey data

Operator Task	Percentage Favorable Responses		
	UAV	UGV	UGS
Plan sensor route(s)-location	100	67	67
Altering sensor routes	33	33	NA
Launch the UAV(s)	0	NA	NA
Monitoring sensor routes	100	67	NA
Monitoring what the sensor is seeing	67	NA	67
Quality of sensor imagery (UAV only)	33	NA	NA
Ability to identify targets	33	0	0
Ability to get accurate far-target location (UGV only)	NA	0	NA
Controlling what the UGV is seeing	NA	33	NA
Manually adjust coverage (UGS)	NA	NA	67
Sending spot reports from UMCS to VC	67	67	NA

Code:
- numbers in columns indicate percent of provided responses.
- green indicates majority of respondents answering favorably.
- yellow indicates respondents had no strong preference.
- red shows a majority answered unfavorably.
- no color indicates a lack of a majority in any category.

Table M-9. Importance of control unit capabilities

Survey Item	Rating
Control one small UAV at a time (8)	6.4
Control one small UGV at a time (8)	5.9
Control more than one small UAV at the same time (8)	5.5
Control more than one small UGV at the same time (7)	5.1
Control multiple systems (UAV/UGV) at the same time (multi-task) (9)	5.4
Monitor one small UAV at a time (8)	6.6
Monitor one small UGV at a time (8)	6.3
Monitor more than one small UAV at the same time (8)	5.8
Monitor more than one small UGV at the same time (7)	6
Monitor multiple systems (UAV/UGV) at the same time (multi-task) (9)	6.1

Code:
- numbers in column represent ratings of importance on a 1 to 7 scale, where 1 represents extremely unimportant and 7 represents extremely important
- numbers in parentheses indicate sample size

Table M-10. Importance of interface characteristics

Survey Item	Rating	Survey Item	Rating
Joystick control (7)	5.7	Multiple map scales (e.g. 1/50, 000 or 1/25,000) (8)	6.5
Voice control/voice recognition (8)	4.9	Record image/video feature (8)	6.1
Touch screen controls	5.6	Transmit image digitally (8)	6.4
Designated buttons	6.1	Take a snapshot image (8)	6.4
Hand off control of vehicle to another distant operator (8)	5.7	Payload interchangeability (8)	6
Greater range from OCU to UAV/UGV (10K or more) (9)	6.1	Visibility of screen in daylight (9)	5.7
Operator selected audible/visual/vibratory alerts and warnings (8)	6	Visibility of screen at night (9)	5.8
Brightness control (8)	5.6	Location of controls (9)	5.6
Volume control (8)	5.4	Size of text and map graphics (9)	5.7
Antiglare screen (8)	5.9	Quality of video image (9)	6.8
Keyboard (part of unit; pop up feature) (8)	5.8	Quality of map overlay (9)	6.3
Imbedded map library (8)	6.5	Detection range of OCU and operator (9)	6.3
Code: - numbers in column represent ratings of importance on a 1 to 7 scale, where 1 represents extremely unimportant and 7 represents extremely important - numbers in parentheses indicate sample size			

Table M-11. Realism of live and virtual operations

Survey Item	Unrealistic	Borderline	Realistic
Providing information to wingmen (9)	11	33	56
Acquiring information from wingmen (9)	11	33	56
Coordinating actions with wingmen (9)	11	22	67
Having a common operational picture with wingmen (9)	11	33	56
Conducting route reconnaissance with wingmen (9)	50	25	25
Conducting area reconnaissance with wingmen (9)	33	33	34
Conducting zone reconnaissance with wingmen (9)	33	33	33
Code: - numbers in columns indicate percent of provided responses. - green indicates majority of respondents answering favorably. - yellow indicates respondents had no strong preference. - red shows a majority answered unfavorably. - no color indicates a lack of a majority in any category.			

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